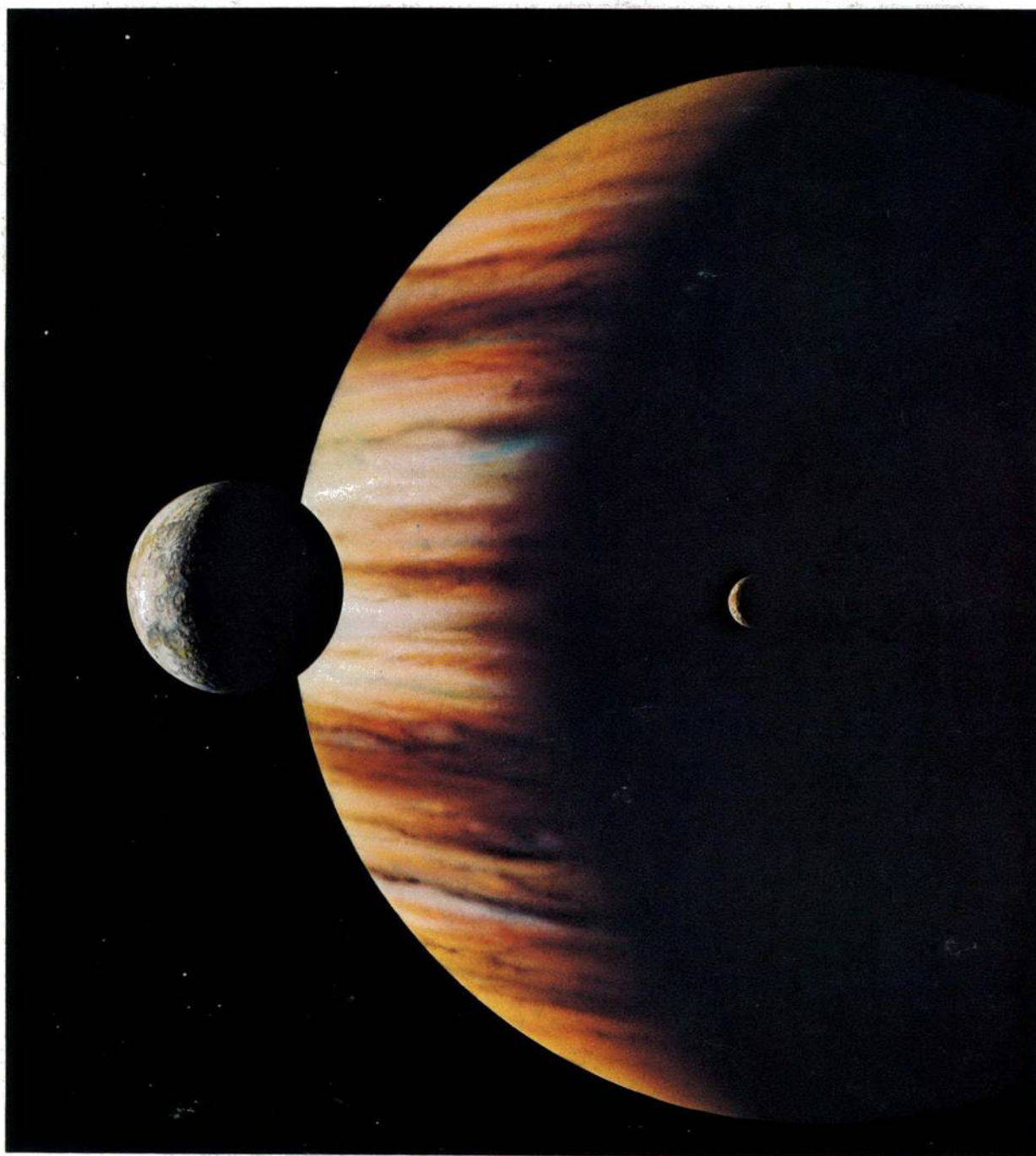


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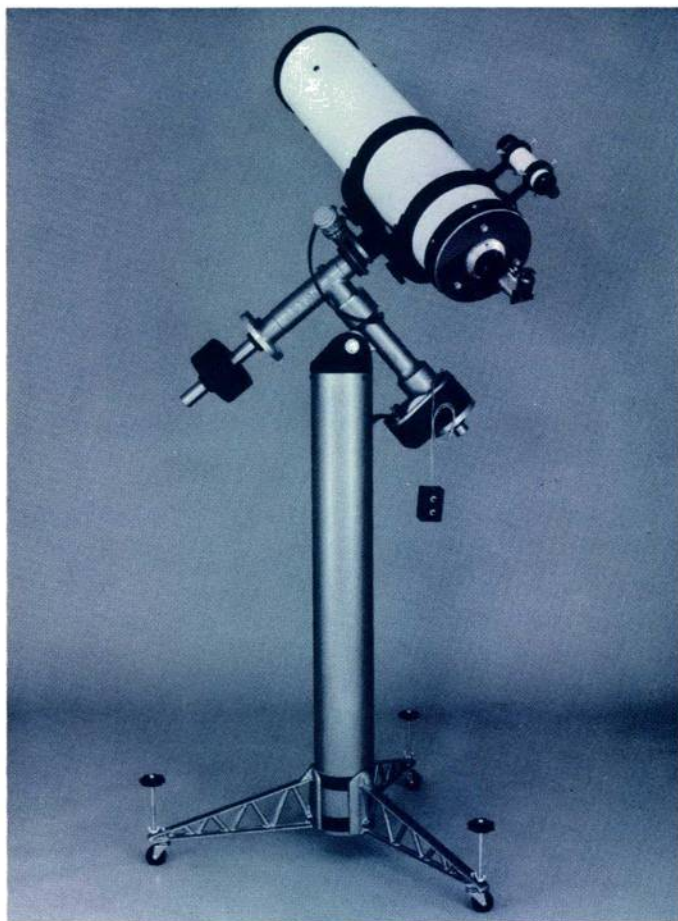
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May 1974

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COVER ILLUSTRATION

Artwork by Victor Costanzo

The crescent Jupiter slices an awesome arc across this view from near the giant planet's second large moon, Europa. Nearer Jupiter roams Io, the inner of four worlds that may never be explored by men. (See "The Forbidden Moons", page 4.)

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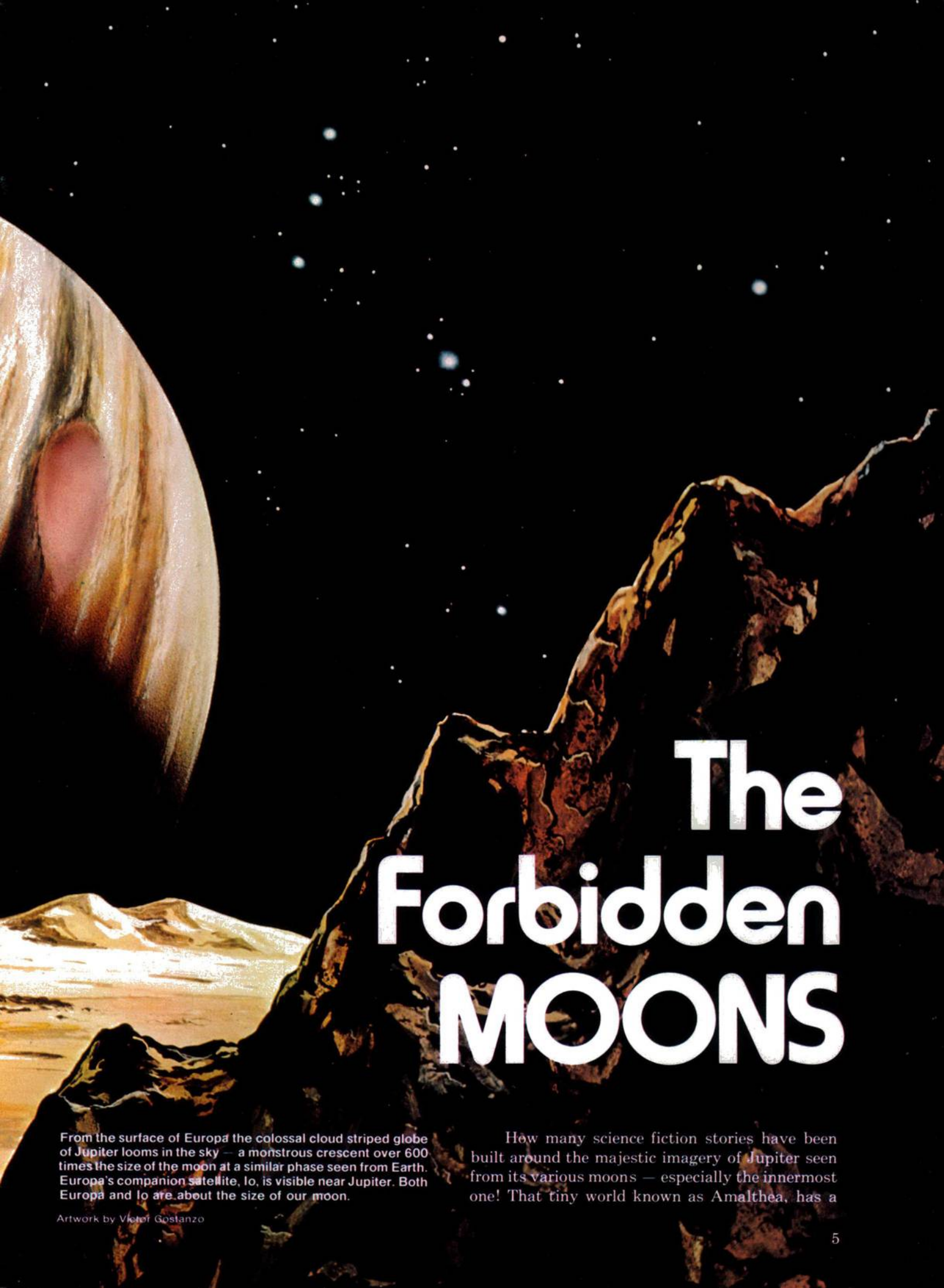
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The Forbidden MOONS

From the surface of Europa the colossal cloud striped globe of Jupiter looms in the sky — a monstrous crescent over 600 times the size of the moon at a similar phase seen from Earth. Europa's companion satellite, Io, is visible near Jupiter. Both Europa and Io are about the size of our moon.

Artwork by Victor Gostanov

How many science fiction stories have been built around the majestic imagery of Jupiter seen from its various moons — especially the innermost one! That tiny world known as Amalthea, has a

vista laid in front of it that is unparalleled in the solar system.

Imagination is carried to its greatest heights in visualizing what it would be like to stand on this asteroid sized moon looking down on the greatest of planets only 70,000 miles away. Jupiter from Amalthea would stretch halfway from the horizon to the zenith and would appear 10,000 times larger and more than 1,200 times brighter than the full moon as seen from Earth. In the sky would be Jupiter's atmospheric quilt of immense complexity — rusts, oranges, yellows and whites. Clouds of all those hues and everything in between would be swirling, changing, in a weather pattern of complexity that we do not understand and a beauty that we may never truly know.

But recent discoveries show that Amalthea and its four big companion satellites are entwined in a magnetic field that holds such intense radiation that it seems unlikely that man will ever walk on any of them. Robot probes, maybe; man, very unlikely.

The sun was obviously a place where robots could be sent plunging to their destruction but man could never venture. But the rest of the solar system seemed wide open for exploration. Yet now we know that the colossal planet has wrapped its five inner attendants in a deadly magnetic embrace. This information is courtesy of Pioneer 10, which in Dec. 1973, swooped by Jupiter and through



NASA Photograph

The shadow of Jupiter's first major satellite Io looks like a bullet hole in this Pioneer 10 view of the giant planet. The shadow is about 1,700 miles wide — the size of the western half of the United States. The detail seen here would correspond to that visible to the unaided eye from the vicinity of Callisto.

The orbits of Jupiter's five inner satellites

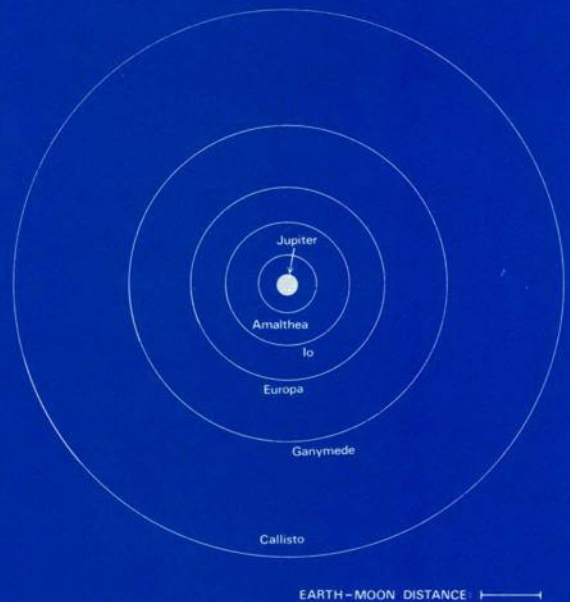


Diagram by Victor Costanzo

a radiation zone that had peak intensities 1,000 times higher than those fatal to human life.

Dr. John Wolf of NASA's Ames Research Center, and the chief scientist of the Pioneer mission, said, "The big moons of Jupiter are out as far as man is concerned. I can't imagine an astronaut making an EVA (extra vehicular activity) under any conditions in the foreseeable future."

Although Wolf did not dismiss the possibility of man landing on the major moons of Jupiter and remaining inside a well protected spacecraft, he quipped, "Who would want to do that? The purpose of sending men to another world is their ability to explore and make firsthand investigations."

So it seems that the exploration of the four big moons of Jupiter, and the little renegade that orbits inside them, will have to be left to the robot craft of the future. And indeed, maybe this is a hint of things to come. Maybe man will be a "stay-at-home" after his brief and courageous leap to the moon. Perhaps the "giant leap for mankind" will be farther and farther in the future as sophistication and versatility of the robot space voyagers become the extensions of man's eyes, hands and mind as we reach out to explore the boulevards of the solar system.

But Jupiter's moons are not toally unknown as the tables on these pages indicate. Let's take a look at them in light of the radiation quarantine. Io, the inner of the "big four" (all discovered by Galileo when he first examined Jupiter through his crude telescope in 1610), is a world where the sights of Jupiter are diminished compared to Amalthea, but still unbelievable. Jupiter would be 2,000 times bigger than the full moon, stretching about a quarter of the way from the horizon to the zenith. When Jupiter would be "full" in the sky its brightness would exceed 200 full moons.

It is only when we move out to Callisto, the outermost of the big four, that the dimensions of Jupiter in the sky become something that we can comprehend. It would appear about 70 times as large as the full moon or about 8-1/2 degrees in diameter — that's four times the diameter that Earth appears in the sky from our moon. And from Callisto the light falling on that moon reflecting from the clouds of Jupiter would equal 13 full moons. So the spectacle of Earth as described by the astronauts is still short of how Jupiter would appear from its most distant major satellite.

But Jupiter has a dozen moons and they are divided very clearly into two groups, based largely on distance from the big planet. The inner group, as shown in the table and diagram, consists of the four Galilean satellites — the big planet sized ones — and little Amalthea which zips around Jupiter in only 12 hours. Beyond this group there is a vast gulf until we encounter three tiny worlds orbiting Jupiter at an average distance of seven million miles; then, four more moons at an average distance of 14 million miles complete the outer group of seven. These last four orbit the planet

backwards or retrograde (clockwise as viewed from above Jupiter's north pole). The rest of the satellites move like most of the other objects in the solar system in a counterclockwise direction around their primaries.

A quick glance at the two orbit diagrams reveals another basic difference between the two groups of Jovian satellites. The outer seven have very elliptical orbits; that is, their individual orbital near points are significantly closer to Jupiter than the far points. Compared with the orderly paths of the inner moons there is a considerable difference.

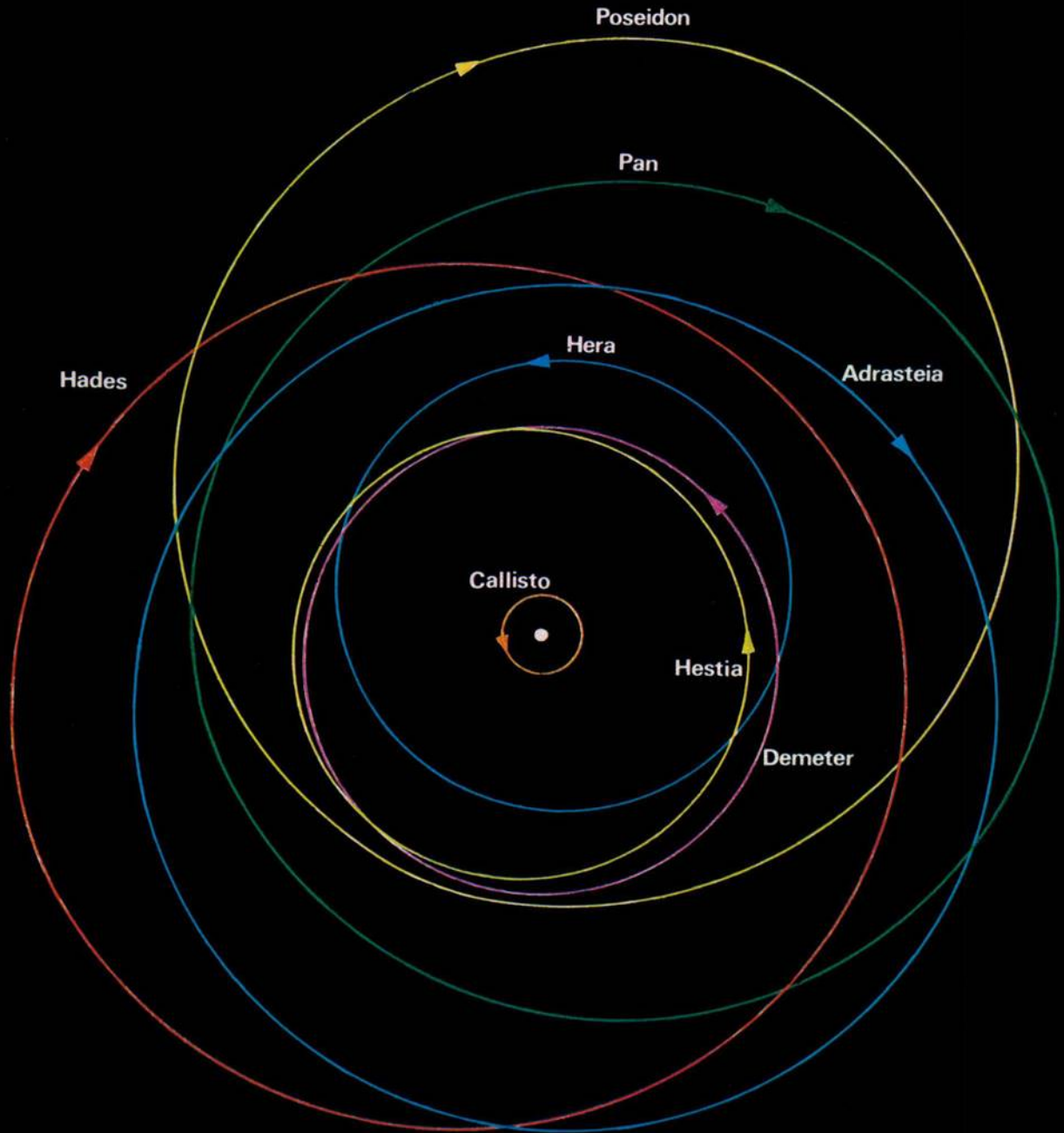
This is really not as much of a paradox as would seem at first. The gravitational grip of Jupiter is much more intense in close and has molded the orbits of the inner moons into virtual circles. This is the most compatible situation under the intense gravitational influence that exists near the planet. In the outer regions there is the influence of the sun to contend with, especially for the outer four satellites. These, it would seem, are certainly captured members of the asteroid zone that peppers the gap between Mars and Jupiter. It is easier for Jupiter to catch an asteroid in a retrograde orbit than a normal or prograde orbit. Hence the outer four are certainly not part of the permanent Jovian system.

Out there at 14 million miles from Jupiter the sun has a significant influence on their orbits producing some real headaches for celestial mechanics experts. Examination of the diagram on page 8 would even suggest that collisions among the outer moons would be a possibility since the tracks of many moons seem to run into each other. However, this is not at all the case since the orbits are all

The Inner Satellites of Jupiter

	Diameter (miles)	Average distance from Jupiter's center	Revolution period	Mass (moon=1)	Density (water=1)	Albedo (percent)
Amalthea (V)	150?	112,000	0 ^d 11 ^h 57 ^m	?	?	?
Io (I)	2273	262,000	1 ^d 18 ^h 28 ^m	1.2	3.5	54
Europa (II)	1850	417,000	3 ^d 13 ^h 14 ^m	0.6	3.1	49
Ganymede (III)	3270	665,000	7 ^d 03 ^h 43 ^m	2.0	1.9	29
Callisto (IV)	3050	1,171,000	16 ^d 16 ^h 32 ^m	1.4	1.7	15

ORBITS OF JUPITER'S OUTER SATELLITES



tipped significantly from the flat orbital plane of the inner moons. Where two lines cross on a flat page, one orbit is actually well above the other.

These seven outer moons, all discovered in the 20th century, have been virtually ignored until very recently. Interest in them was so low that they never even received names. The names that we have listed here are ones that are coming into general use but, for some reason, are not considered official. (The Roman numerals in the tables are their recognized designations; for example, Poseidon is known as JVIII.) This situation should rapidly change and the names seen here, although unfamiliar to many, should become commonly used and even well known before the end of the 20th century. Why? Because it is on these moons that future space missions are going to find the most hospitable conditions in the Jovian environment.

A space mission to the inner moons is always going to be subjected to damaging radiation near Jupiter. Robot spacecraft may eventually be able to be shielded against the intense radiation in the realm of the inner moons. Even so, the swooping orbits of the outer moons, their relative freedom from the more intense radiation of the planet, and their extremely low gravity makes them virtually ideal artificial satellites upon which to conduct investigations.

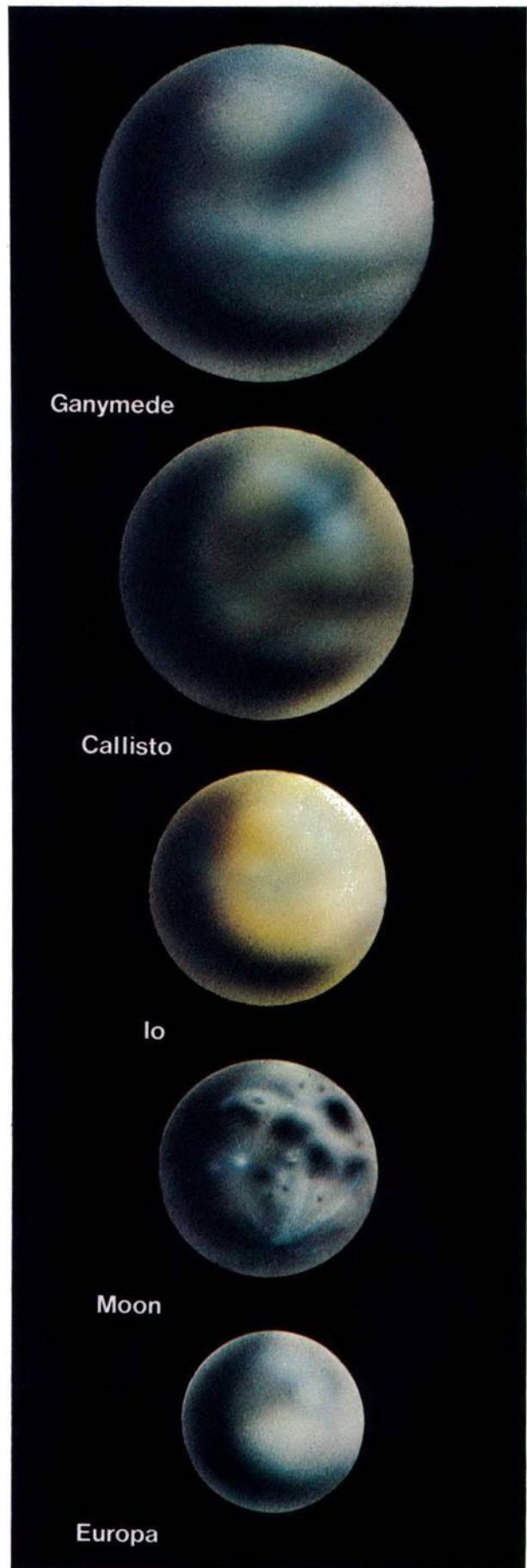
Those investigations will probably be of two types. First, an examination of the nature of the moon itself to see if it is made of the same stuff as the asteroids and to see what class of asteroid it is and thus deduce its history; and second, to utilize a vantage point of Jupiter that exploits the great inclination of the satellite's orbit and its varying distance from Jupiter while all the time remaining outside the danger limit of the radiation zone.

Making observations of Jupiter from the inner moons as well as being an enterprise unfit for man will probably be a challenge for robot craft as well since two of the moons are known to have thin atmospheres (Io and Ganymede). Perhaps the other two major moons have less significant atmospheric shrouds. Future exploration will tell.

The next scheduled exploration of Jupiter will

Jupiter's outer family of seven moons have orbits that carry them up to 20 million miles from the giant planet — much farther than any other planet's moons. These outer, mountain sized minimoons swing through giant elliptical orbits, four of which are backwards or retrograde. Although there seem to be many intersecting points, one orbit is always inclined above or below another. Artwork by Victor Costanzo

The four large satellites of Jupiter are compared in size to Earth's moon. Of the four, Io and Ganymede are known to have thin atmospheres. Artwork by Victor Costanzo



The Outer Satellites of Jupiter

	Estimated diameter (miles)	Revolution period (days)	Average distance (millions of miles)	Minimum distance (millions of miles)	Maximum distance (millions of miles)	Inclina- tion of orbit to Jupiter's equator
Hestia (VI)	90	251	7.1	6.0	8.2	28°
Hera (VII)	50	260	7.3	5.8	8.9	28°
Demeter (X)	15	264	7.4	6.7	8.2	29°
Adrastea (XII)	15	631	13.2	10.9	15.5	147°
Pan (XI)	20	693	14.0	11.0	16.9	163°
Poseidon (VIII)	15	739	14.6	8.6	20.6	148°
Hades (IX)	20	758	14.7	10.7	18.7	157°

be by Pioneer 11 (a twin of Pioneer 10 which passed by Jupiter in Dec. 1973 and provided, among other things, the spectacular photographs displayed in the February and April issues of *ASTRONOMY*). Pioneer 11 will swoop by Jupiter in December of this year and be flung onto a trajectory directing it toward Saturn. What happens at Saturn has not yet been decided. The spacecraft may be sacrificed in a probable suicide dive through the rings. Or it may be targeted outside the rings, or on an exceedingly dangerous venture between the inside edge of the rings and the planet itself. All of these options are open as well as a last minute decision not to send the craft to Saturn at all. Once the decision is made to send the craft to Saturn (and this seems to be the likely course of events), the final decision can wait for some time since it will take nearly five years to get to the ringed planet (see *Astro-News*).

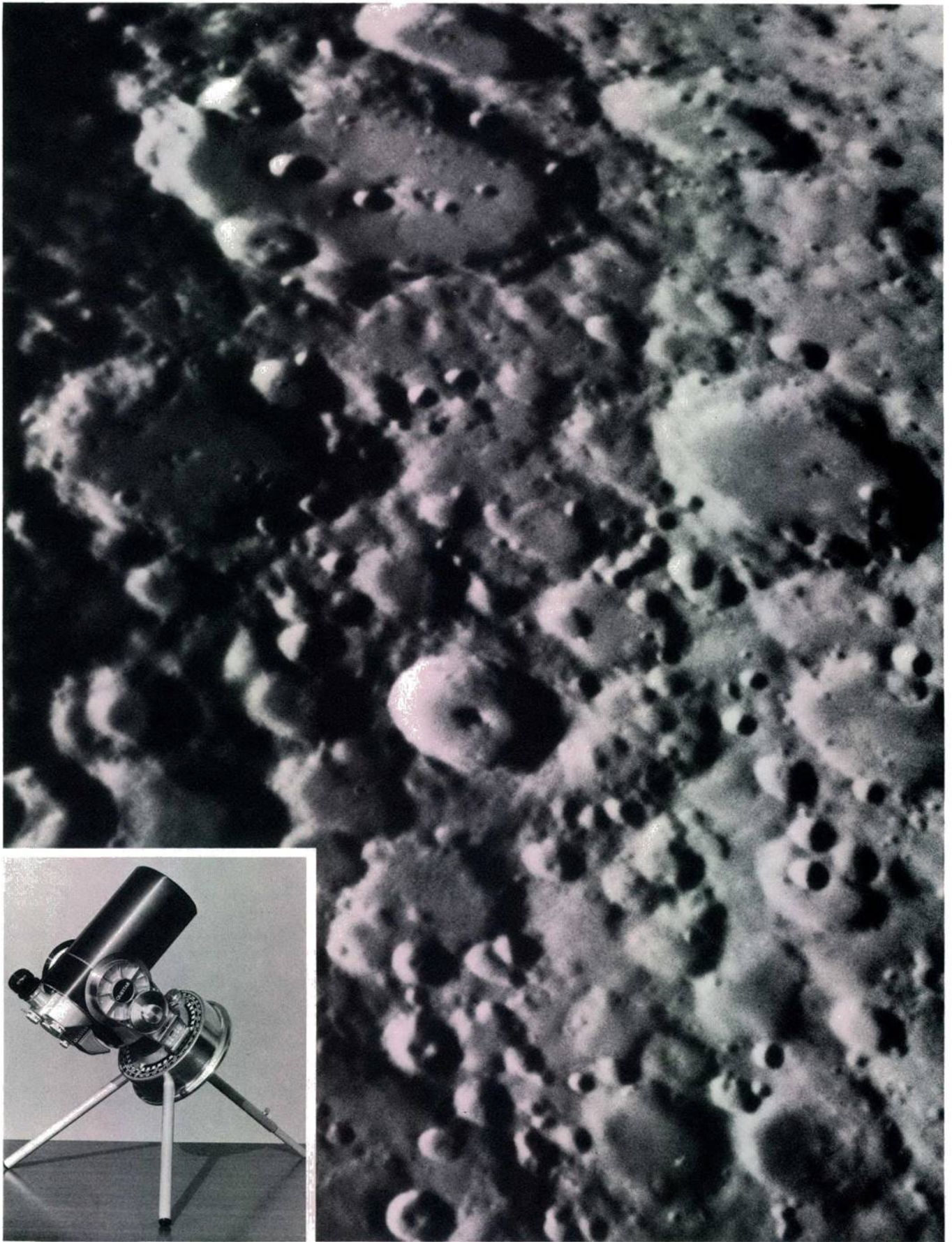
Following Pioneer 11, Mariners 11 and 12 will be targeted to Jupiter and its moons. These will be highly sophisticated, photographic reconnaissance flybys similar to the Mariner 10 flyby of Venus and Mercury earlier this year. The cameras of these spacecraft will be capable of much higher resolution than the spectacularly successful Pioneer 10. They will make detailed scrutinies of the five inner satellites, the clouds of Jupiter and especially the intriguing Great Red Spot. Both of these craft will be hurtled by Jupiter's mighty gravitational attraction onto speeded up paths to eventual encounter with Saturn and possibly Uranus. Those missions are planned for launch in the late 1970s for encounter with Jupiter around 1980. Planned for launch in the early 1980s are similar Mariner spacecraft, this time equipped to go into orbit around Jupiter with a near point somewhere

around Amalthea and a far point well beyond the orbit of Callisto. Later on in the orbiting mission, the path of this future Mariner may be trimmed to make the near point a little bit farther out to protect the craft from prolonged radiation exposure.

Beyond the Jupiter orbiters are landing missions on the moons. But a landing requires fighting Jupiter's gravity as well as the satellite's. Current technology is not up to the task — at least for the inner moons. So a mission to an outer satellite is even more desirable from a feasibility standpoint. Despite the various setbacks the most desirable target will ultimately be Io, with its greater mass and density than our own moon and possible metallic core overlain by moonlike rock and dust with some ice mixed in. An examination of the thin atmosphere, that today is thought to have a density of about one thousandth that of Earth's, is particularly desirable. It will be analysis of this atmosphere, experimentation in soil analysis on the surface, and ultimately a roving vehicle with a television camera to trundle across the surface of Io, that will provide man's information about a world that he may never walk on.

And the same can be said for Europa, Ganymede and Callisto — worlds that have been examined telescopically for over three centuries and dreamt about by decades of science fiction writers. These are worlds where, in imagination, astronauts have walked, and where tourists from Earth have stood and gawked at the ocean of Jovian clouds spread before them.

Yes, it was a beautiful picture — one that some thought was perhaps within many of our lifetimes. But now it seems that the four planet sized moons that swing around the alien giant are, for 20th century man anyway, forbidden. 

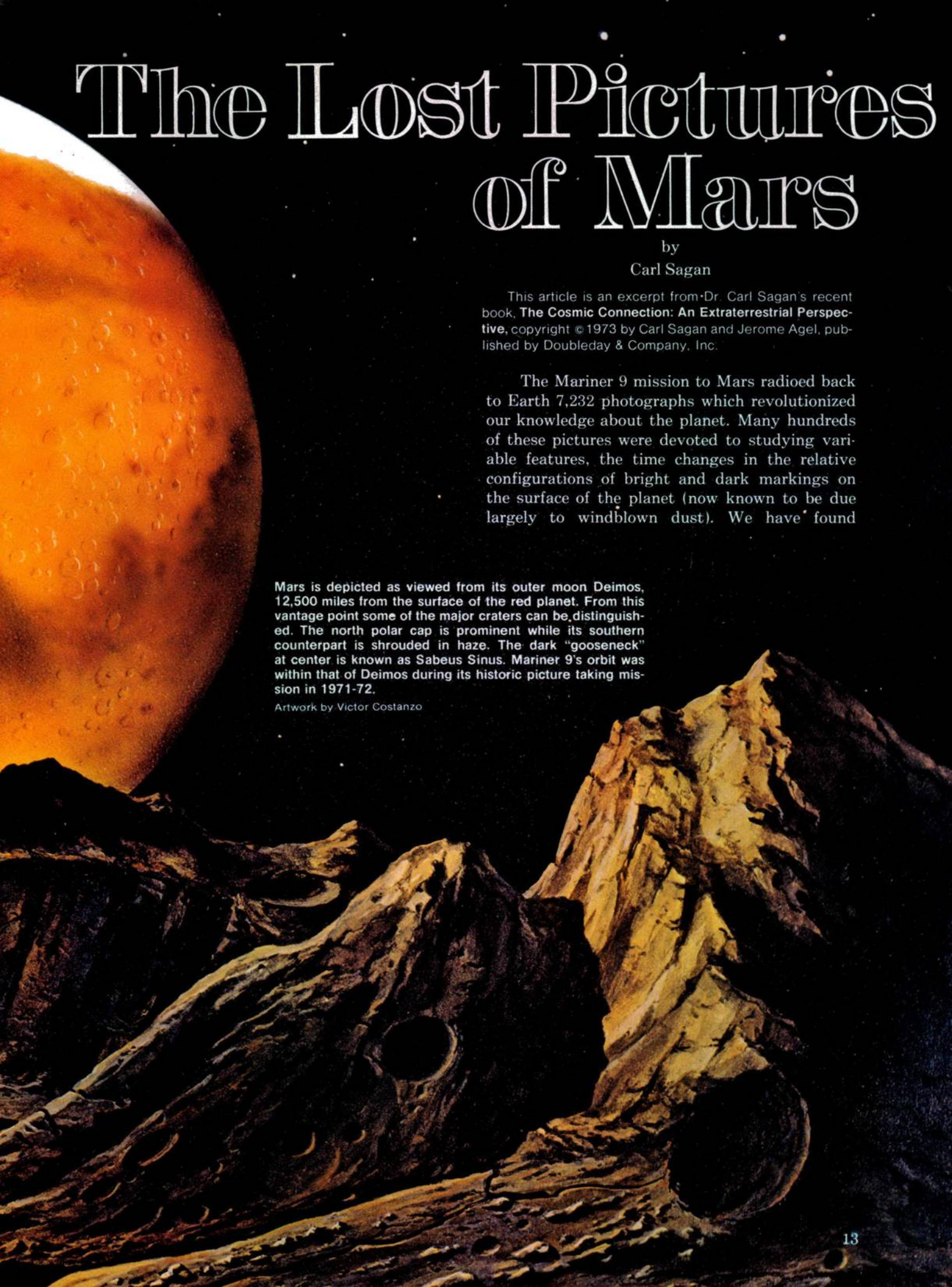


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The Lost Pictures of Mars

by
Carl Sagan

This article is an excerpt from Dr. Carl Sagan's recent book, **The Cosmic Connection: An Extraterrestrial Perspective**, copyright © 1973 by Carl Sagan and Jerome Agel, published by Doubleday & Company, Inc.

The Mariner 9 mission to Mars radioed back to Earth 7,232 photographs which revolutionized our knowledge about the planet. Many hundreds of these pictures were devoted to studying variable features, the time changes in the relative configurations of bright and dark markings on the surface of the planet (now known to be due largely to windblown dust). We have found

Mars is depicted as viewed from its outer moon Deimos, 12,500 miles from the surface of the red planet. From this vantage point some of the major craters can be distinguished. The north polar cap is prominent while its southern counterpart is shrouded in haze. The dark "gooseneck" at center is known as Sabeus Sinus. Mariner 9's orbit was within that of Deimos during its historic picture taking mission in 1971-72.

Artwork by Victor Costanzo

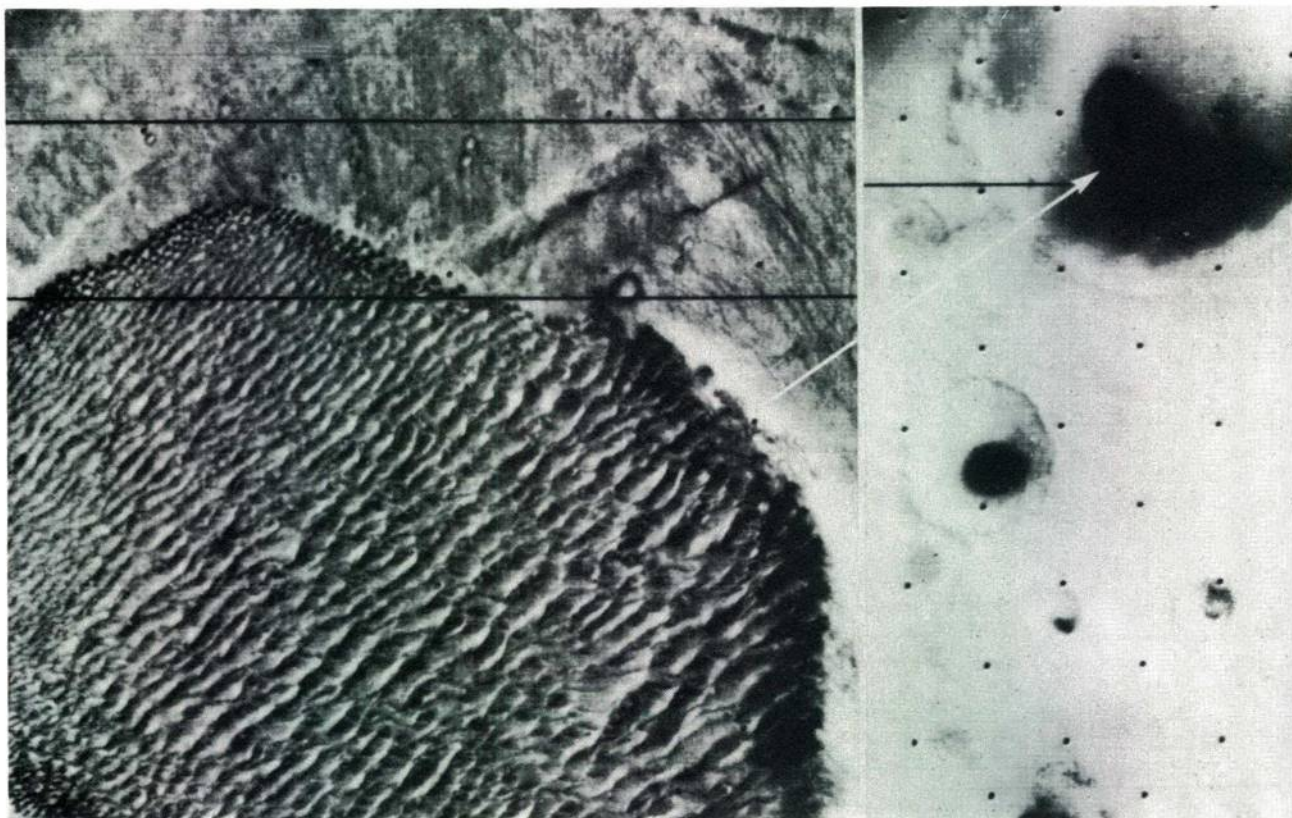
thousands of bright and dark streaks, beginning in local impact craters and stretching across tens of miles of Martian surface. They point in the direction of the prevailing winds. We think they are produced by high winds carrying dust out of the craters and depositing it on the surface beyond the crater ramparts. These streaks are natural wind direction indicators and perhaps anemometers laid down on the Martian surface for our edification and delight. We have discovered dark irregular patches or splotches, mostly residing in the interiors of craters, which tend to lie on the leeward walls of the craters. Thus the splotches as well as the streaks are wind indicators. Some of the splotches have been resolved by Mariner 9 into enormous fields of parallel sand dunes.

We have discovered many cases of dark streaks and splotches varying through the mission in outline or extent. The positions and variabilities of these dark features correspond well to the classical dark markings of Mars, observed by ground based observers for more than a century and most often attributed by them to seasonally changing dark vegetation on the Martian surface.

But our Mariner 9 evidence points unambiguously to a meteorological, rather than a biological, explanation of the Martian seasonal changes.

This in no way excludes life on Mars. It merely means that if there is life on Mars, it is not easily detectable over interplanetary distances. The same is true in reverse: photographic detection of life on Earth from the vantage point of Mars is impossible, as we have found by studying several thousand orbital photographs of our own planet. But the time-varying streaks and splotches on the Martian surface are a new and most exciting Martian phenomenon which cries out for further study.

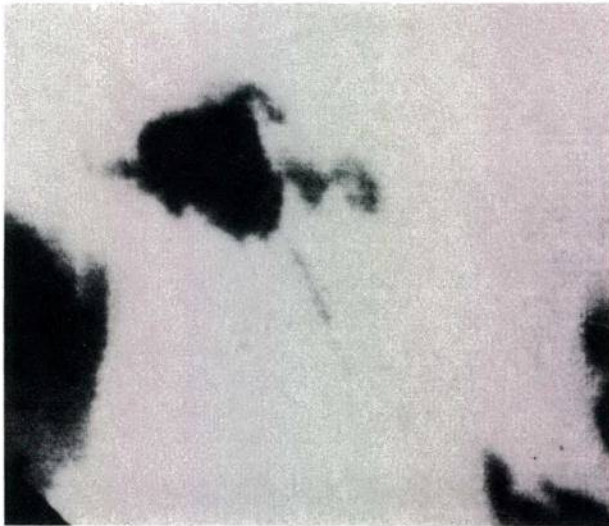
Since the Martian changes occur slowly, the variable-features objectives required very long time intervals between two pictures of the same region to see what changes had occurred. At the very end of the mission, 15 photographs were successfully taken by the Mariner 9 cameras of regions in Syrtis Major and Tharsis, important for understanding the long term variations. But when the time came to point the high gain antenna of Mariner 9 to Earth, so that these pictures could be transmitted by playing back the spacecraft's



NASA Photograph

The sands of Mars are real. This 25 mile wide dune field lies within a Martian crater. It was first seen only as a dark patch in a low resolution Mariner 9 photograph (right). As in the dune fields on Earth, the dunes at the margin of the field are

smaller than those near the central parts. The larger dunes are at least 300 feet high. Strong winds blowing from a constant direction are responsible for this feature. The winds on Mars are believed to occasionally exceed 200 m.p.h.



An astounding change on Mars in the region of Promethei Sinus, near the south pole of Mars, is seen in these two Mariner 9 photographs. The leaf shaped patch — which is equivalent in area to a few thousand football fields — suddenly

tape recorder, the last of the attitude-control gas was used up, Earthlock could not be acquired, and playback did not occur. The spacecraft had literally run out of gas.

About a year before the Mariner 9 mission was launched, the possibility was raised that the spacecraft would run out of control gas. A solution was proposed: that the propulsion tanks be connected to the attitude-control gas system — a kind of spacecraft anastomosis. Excess propulsion gas could then be used for attitude control in case the attitude-control nitrogen was exhausted. This possibility was rejected — largely because of its expense. It would have cost \$30,000. But no one expected Mariner 9 to last long enough to use up its attitude-control gas. Its nominal lifetime was 90 days — and it lasted almost a full year. The engineers had been overly conservative in assessing their superb product.

In retrospect, it sounds very much like false economy. With an adequate supply of attitude-control gas, the spacecraft might have lasted another full year in orbit around Mars. About \$150 million of science might have been bought for \$30,000 worth of pipe. Had we known that the spacecraft would die from lack of nitrogen, I am almost certain that the planetary scientists involved would have raised the \$30,000 themselves.

In fact, there are many such critical junctures in the space program where the addition of only a small amount of money can greatly increase the scientific return from a given mission. But NASA, severely limited by funding limitations imposed by Congress, the White House, and the



NASA Photograph

developed within a 13 day period. Such changes, which are thought to be due to windblown dust, have been extensively researched by the author, an international authority on Mars.

Office of Management and Budget, has not had such small increments of money. If it were possible, and if a generous donor could be found, this would be a superb use for private philanthropy.

But these are idle musings. No anastomosis was performed; the final playback was not accomplished. Sitting there still on the Mariner 9 tape recorder are 15 vital photographs of the planet. They will never be returned under Mariner 9's own power. It has now also lost solar lock; sunlight is no longer being converted to electricity on its four great solar panels, and there is no way to reactivate it. We may never know what Tharsis and Syrtis Major looked like around the beginning of Nov. 1972, from the vantage point of Martian orbit.

Or perhaps we will. Mariner 9 is in an orbit which is slowly decaying in the Martian atmosphere. But the decay is so slow that the spacecraft will not crash into Mars for another half century. Long before then there should be manned orbital flights around Mars. Rendezvous and docking maneuvers are reasonably well developed in manned missions even now. Perhaps sometime around 1990, as a small side trip in a grand manned orbital exploration of Mars, there will be a rendezvous with Mariner 9. The old and battered spacecraft will be taken aboard a large manned station and returned home — perhaps to be put in the Smithsonian Institution; perhaps to prevent terrestrial microorganisms on Mariner 9 from reaching Mars; but perhaps also to rescue and read off the 15 lost pictures of the Mariner 9 mission. 🐞

ROBERT FROST:

Poet of the Stars

by
Maxwell Corydon Wheat

"The best thing that we're put here for's to see;
The strongest thing that's given us to see with's
A telescope. Someone in every town
Seems to me owes it to the town to keep one."

With these words a fellow named Brad McLaughlin burned his house down for the insurance so he could afford a telescope to find out "about our place among the infinities." He did it in a poem called "*The Star-Splitter*", written by Robert Frost.

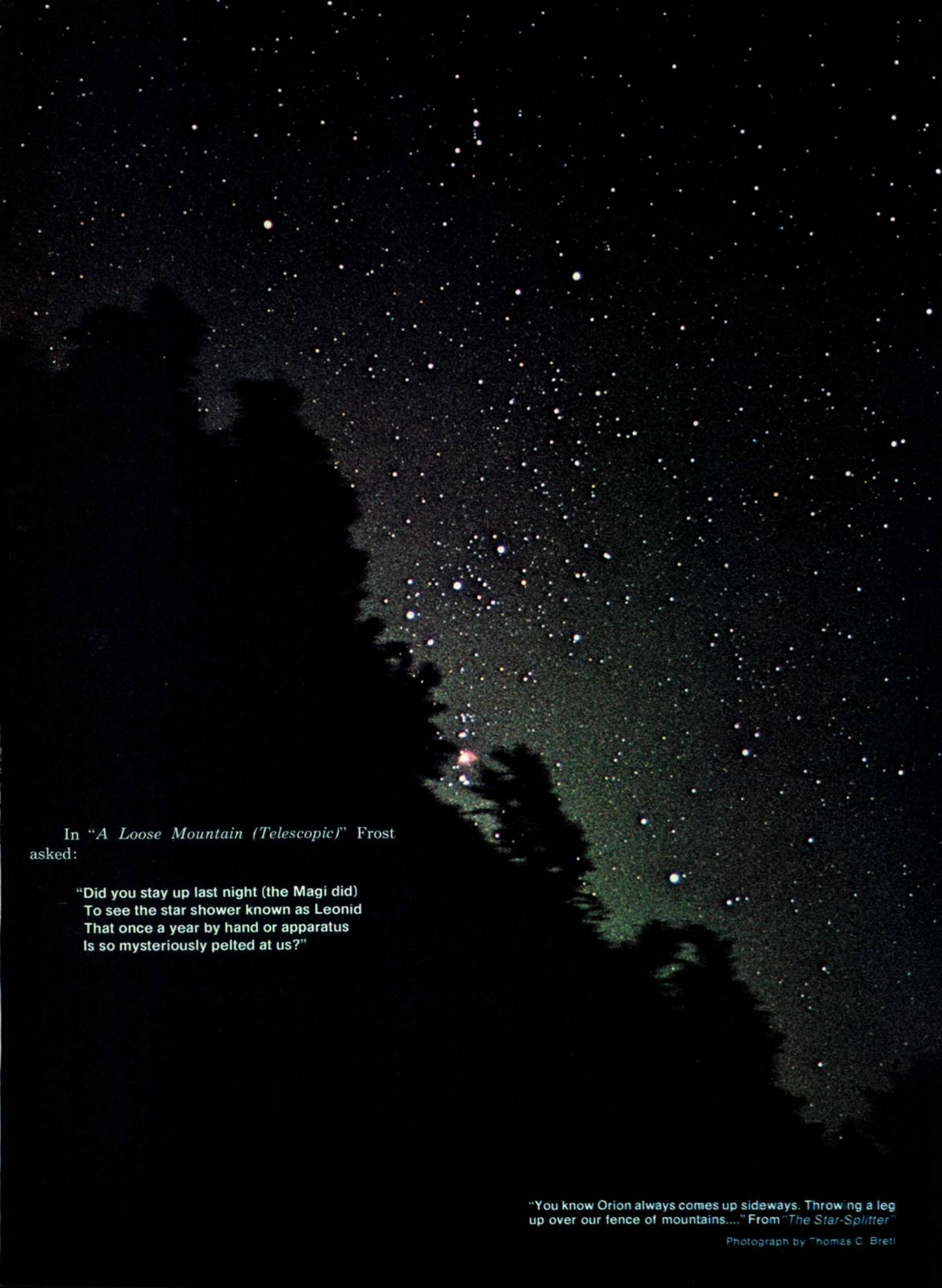
This is the centennial year of Frost's birth on March 26, 1874 in San Francisco, Calif. One of America's greatest poets, he was a kind of Brad McLaughlin; he felt it was important to show the beauty, wonder and mystery of the universe through much of his poetry.

Constellations, planets and meteor showers illuminate the literary sphere of this artist who died in 1963. In turn Frost illuminated celestial phenomena with his graphic images. "*Canis Major*" is:

"That heavenly beast
With a star in one eye..."

He described Venus in "*The Literate Farmer and the Planet Venus*" as sometimes:

"...the bright and only one
In sunset light, you'd think it was the sun
That hadn't sunk the way it should have sunk,
But right in heaven was slowly being shrunk
So small as to be virtually gone,
Yet there to watch the darkness coming on..."



In "*A Loose Mountain (Telescopic)*" Frost
asked:

"Did you stay up last night (the Magi did)
To see the star shower known as Leonid
That once a year by hand or apparatus
Is so mysteriously pelted at us?"

"You know Orion always comes up sideways. Throwing a leg
up over our fence of mountains...." From "*The Star-Splitter*"

Photograph by Thomas C. Bretl

Since 1974 is his 100th anniversary year, an astronomy organization could schedule a reading of a few astronomical poems by Frost as a part of a meeting. Poems could include "*On Looking Up by Chance at the Constellations*" about motions of heavenly objects; "*Evening in a Sugar Orchard*", where sparks from the fire in a maple sugar-house seem to mingle among the stars of Leo, Orion and the Pleiades, and "*Two Leading Lights*" which compares the sun and moon.

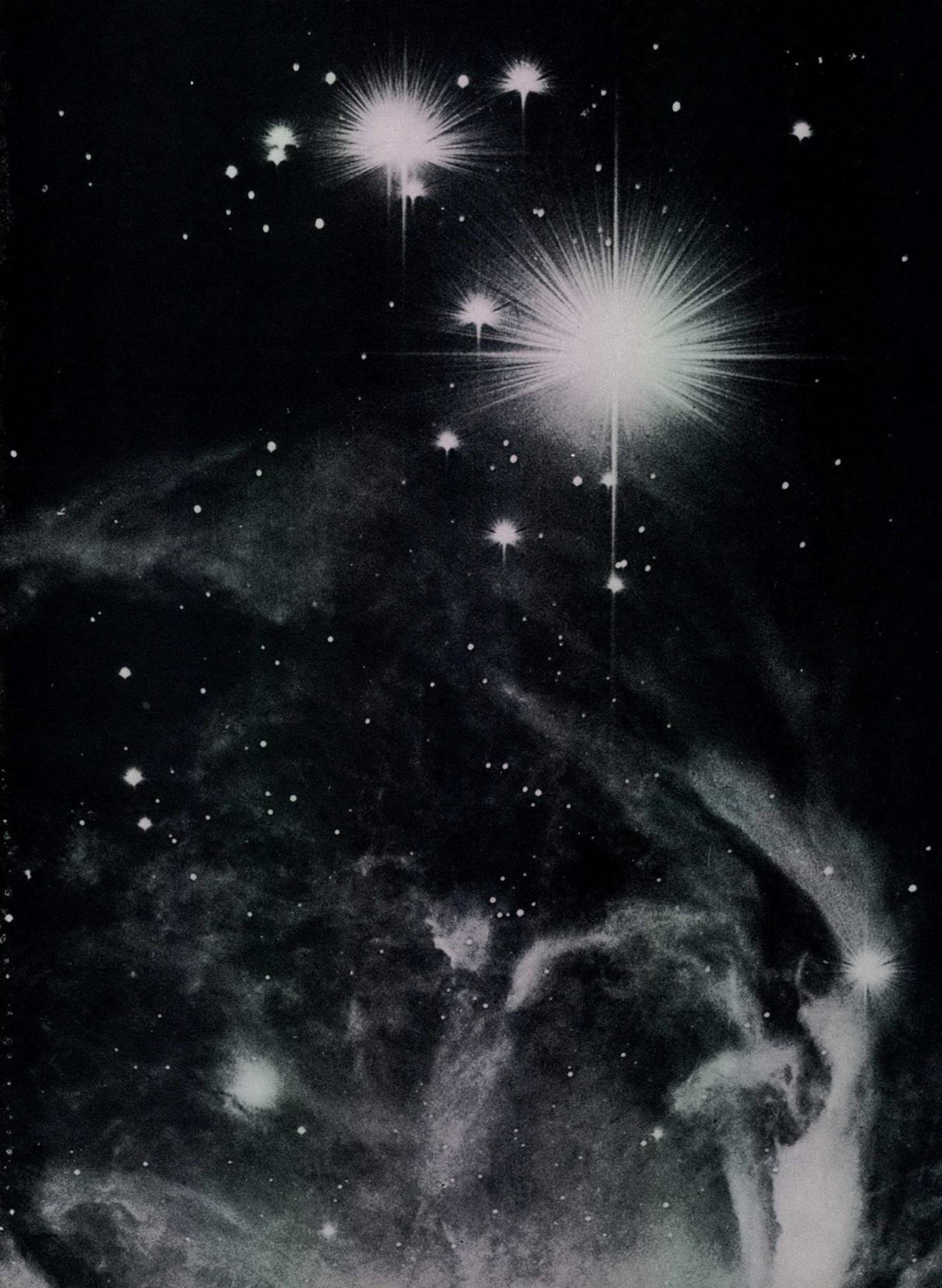
Frost became fascinated with astronomy when he was 15 after consuming the book, **Our Place Among the Infinities**. (He later used this title as a phrase in "*The Star Splitter*". Written by British astronomer Richard Anthony Proctor, the book motivated the boy to sell subscriptions for **The Youth's Companion** magazine — with his mother helping by pawning some off on her friends — to win a telescope that was offered as a prize for selling a certain number.

When the instrument arrived at the gaunt, three story brick home on Haverhill St. in Salem Depot, N.H., Frost converted his bedroom into an observatory. He rigged a black curtain over the window to block the village lights and cut a hole just large enough to slide in the telescope.

"He has been astronomical ever since," his wife wrote a friend from Key West, Fla., where they vacationed in 1935. "He says he is down here in Key West now chiefly to find out if Canopus is as good a star as Sirius," Mrs. Frost reported.

As an amateur astronomer, Frost knew that Canopus, Sirius and all the stars were infernos of burning elements. He revealed this awareness in "*Choose Something Like a Star*".

"O Star (the fairest one in sight)....
Say something to us we can learn
By heart and when alone repeat.
Say something! And it says, 'I burn.'"







How overwhelmingly impersonal! Yet, people look to the familiar points of light for reassurance as Frost demonstrated in this poem's conclusion.

"So when at times the mob is swayed
To carry praise or blame too far,
We may choose something like a star
To stay our minds on and be staid."

Photograph by J.D. Kousbaugh





He sharply portrayed the gap between human emotion and the reality of the universe in the poem "Stars".

"How countlessly they congregate
O'er our tumultuous snow....
As if with keenness for our fate....
And yet with neither love nor hate...."

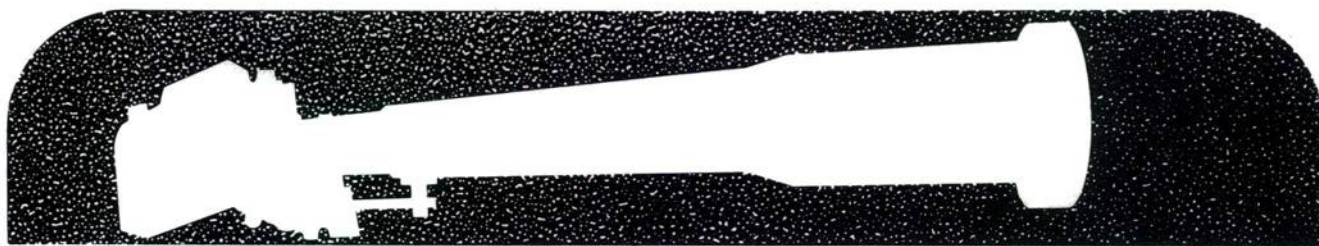
Frost did not attempt to resolve questions "about our place among the infinities". Instead, in a poem like "*The Star-Splitter*", he focused the readers' wonder on the beauty and strength of human persistence in endlessly seeking the answers the universe never surrenders.

"I recollect a night of broken clouds
And underfoot snow melted down to ice,
And melting further in the wind to mud.
Bradford and I had out the telescope.
We spread our two legs as we spread its three,
Pointed our thoughts the way we pointed it,
And standing at our leisure till the day broke,
Said some of the best things we ever said.
That telescope was christened the Star-splitter,
Because it didn't do a thing but split
A star in two or three the way you split
A globule of quicksilver in your hand
With one stroke of your finger in the middle.
It's a star-splitter if there ever was one
And ought to do some good if splitting stars
'Sa thing to be compared with splitting wood.
We've looked and looked, but after all where are we?
Do we know any better where we are,
And how it stands between the night tonight
And a man with a smoky lantern chimney?
How different from the way it ever stood?"

All quotes from "*Complete Poems of Robert Frost*" (1964);
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PHOTOGRAPHY IN ASTRONOMY

Slide Copying Improves Color Photos

by
Stephen C. Reed and Chet Bart

A significant expenditure of time and a great deal of work is usually required before you, the astrophotographer, obtain even a few clear, well guided and properly exposed color photographs. Once the slides are returned from the commercial processing laboratory you might assume that that's the end of your creative input. Not so!

The 10 minute photo of the Pleiades and Hyades (top) was taken on GAF 500 film and later duplicated (bottom) to bring out the detail of the two star clusters.

Photographs by Chet Bart

Fortunately, it is still possible to improve the slides.

By copying the slides you can selectively crop or increase contrast, as well as control image size, color balance and density. Neither extensive experience nor complex equipment is required to substantially improve your color astrophotographs. Although you can achieve good results with simple apparatus, use of specialized equipment will certainly be more convenient.

The preferred setup (used to obtain the ac-

companying photographs) is a single lens reflex camera attached to a bellows fitted with a commercial slide copier. The advantages inherent in this equipment are: continually adjustable magnification for selective cropping, proper baffling to eliminate stray light, high quality optics, possible through-the-lens light metering, lack of vibration during exposure (because the optics, slide and camera are rigidly clamped together), and most importantly, the ability to precisely position the original slide exactly parallel to the film plane.

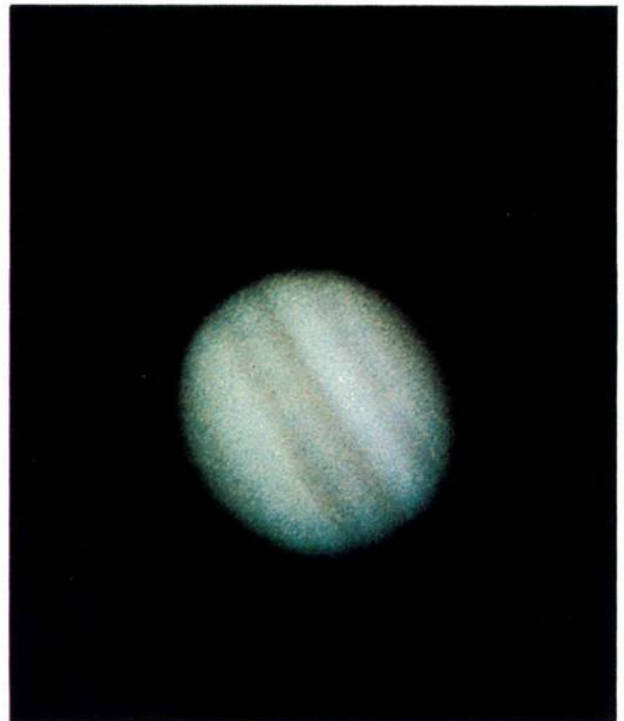
The actual mechanics of operating this equipment will vary depending on the brand and features of the particular slide copier you use. Regardless of the brand of equipment used, depth of focus is extremely small at the close working distances involved in slide duplicating so special care should be taken to insure maximum image sharpness. The copier should be focused with the lens wide open. Stop down normal lenses as far as possible for exposure. Most good lenses do not shift focus when stopped down and the slight increase in depth of focus at small apertures (large "f" values) helps correct focusing errors as well as field curvature. With macro or copy lenses (designed to be used for extreme close-ups), the sharpest "f" stop is usually two stops smaller than the maximum aperture. As you might expect, macro and copy lenses provide the best results, but most normal camera lenses are entirely satisfactory if used at, or near, minimum aperture.

If a slide copier is not available, there are alternate ways to copy slides. For example, a single lens reflex camera may be fitted with extension tubes or bellows and the slide copied providing the light source behind the transparency is properly diffused. The slide must be parallel to the film plane if the results are to be similar to those achieved with the complete but more expensive slide copier.

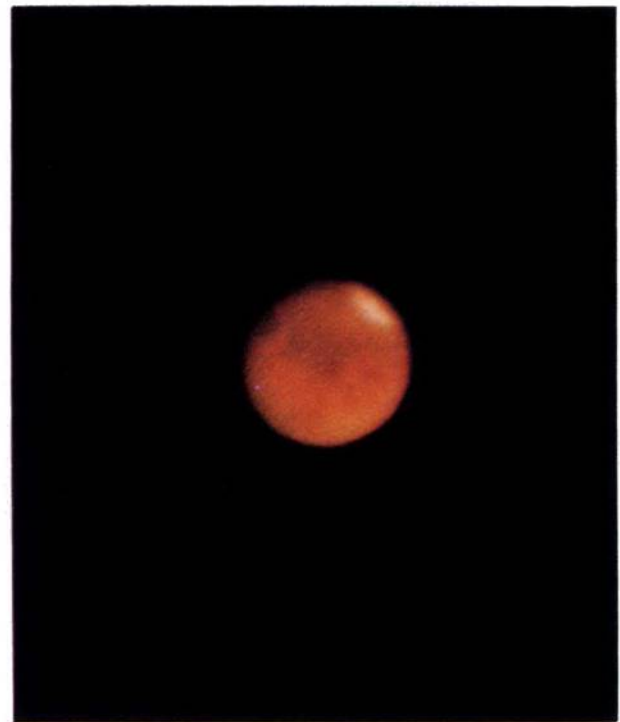
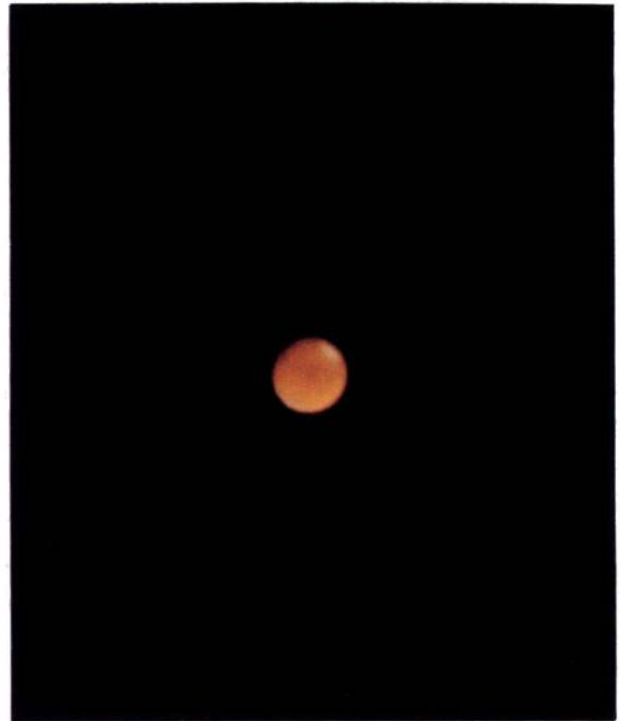
Small, inexpensive T-mount slide copiers with internal optics are available, but their flexibility is limited and they generally have poor resolution at the edge of the field.

If you don't have access to bellows or copying units, it is possible to photograph the projected image of the transparency, using only a slide projector and matte white screen or rear projection screen. Although this is the least desirable method, satisfactory results may be achieved if the projector lens is of good quality and if the slide itself remains relatively flat when subjected to the heat of the projection lamp.

The advantage of rear projection is that it



eliminates shadows when you want to close in on your subject. Keep the camera perpendicular to the screen and move it around to give the desired composition and magnification. When a short projection distance is used, it probably will be necessary to put a dodging disk (an opaque disk cemented on glass) in the path of the projector's beam to eliminate excessive central screen brightness.



No matter what type equipment you use, the light source must be matched to the type of film being used in order to give the desired color balance in the final transparency. Color film balanced for daylight is the most common and easiest to obtain, but to retain color balance close to the original requires either daylight itself, special 5000 degree Kelvin fluorescent light, electronic flash, or properly filtered (80 series)

Jupiter, Mars and the North American nebula all take on added size and contrast when duplicated by the methods described in this article. An off center image can be centered and enlarged to give pleasing compositions that often show more detail than the original. The Mars photo, taken July 18, 1971, is a 1-1/2 second eyepiece projection exposure on High Speed Ektachrome through an eight inch reflector. The one second Jupiter photo was taken with the same equipment on Aug. 19, 1973. For the nebula photo on GAF 500 film, Reed guided a camera with a 50mm f/2 lens for 30 minutes. All photos were taken from Mt. Pinos near Los Angeles, Calif.

Photographs by Stephen C. Reed

tungsten illumination. When only a few duplicates are desired this latter combination is probably the most convenient since the balance of the roll is available for general photography. In cases where the bulk of the roll of film will be devoted to tungsten illumination, High Speed Ektachrome Type B is more convenient because it does not require the use of filters (see table).

Low voltage, high intensity lamps, opal enlarger lamps, and projector lamps are acceptable as tungsten light sources. Electronic flash, which is approximately daylight in color quality, is also an excellent light source. It will, however, provide somewhat lower contrast than tungsten illumination — an effect not necessarily desirable for astronomical subjects. As with most types of photography, it will be necessary to test and bracket exposures to determine the proper exposure for all expected conditions.

The color balance of duplicate slides may be altered in a controlled manner by using standard color compensating filters. However, it is necessary to be able to duplicate the original color balance in order to predict what effect the color compensating filters will produce. Use color compensating filters complementary in color to the color you want to reduce (see table). Rarely will a filter density greater than 0.10 or 0.20 be re-

quired but some trial and error will be necessary at first. When altering the sky color of star field photographs, take care that stars do not take on the color of the filter. As long as the filter is fairly light, the points representing star images should receive sufficient exposure so that the color shift will not be apparent.

It is difficult to give specific information on exposure times since they vary with the light source and optical characteristics of the copying setup as well as the film speed and "f" stop being used. If your camera has a through-the-lens metering system, use the exposure indicated as a starting point. Bracket to insure getting the best possible exposure. If internal metering is not possible, an exposure meter can be used to measure the incident light at the slide position. The appropriate bellows correction factors can be calculated and applied to give a starting point.

When this same technique is used to photograph black and white negatives with a clear based black and white film, it yields black and white positives which may be mounted as slides. The resulting images have much greater density range and more brilliance than conventional photographic prints and often present faint nebulosity that cannot be recorded on photographic paper. ☛



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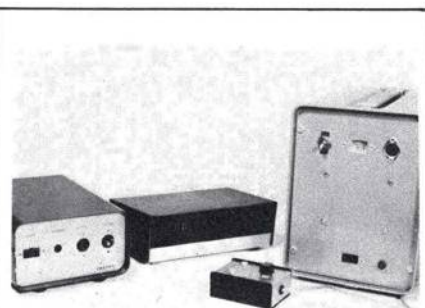
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MAY

Stars in each constellation are indicated, in order of brightness, with the Greek Alphabet.

α Alpha	η Eta	ν Nu	τ Tau
β Beta	θ Theta	ξ Xi	υ Upsilon
γ Gamma	ι Iota	$\omicron$ Omicron	ϕ Phi
δ Delta	κ Kappa	π Pi	χ Chi
ϵ Epsilon	λ Lambda	ρ Rho	ψ Psi
ζ Zeta	μ Mu	σ Sigma	ω Omega



MAGNITUDES

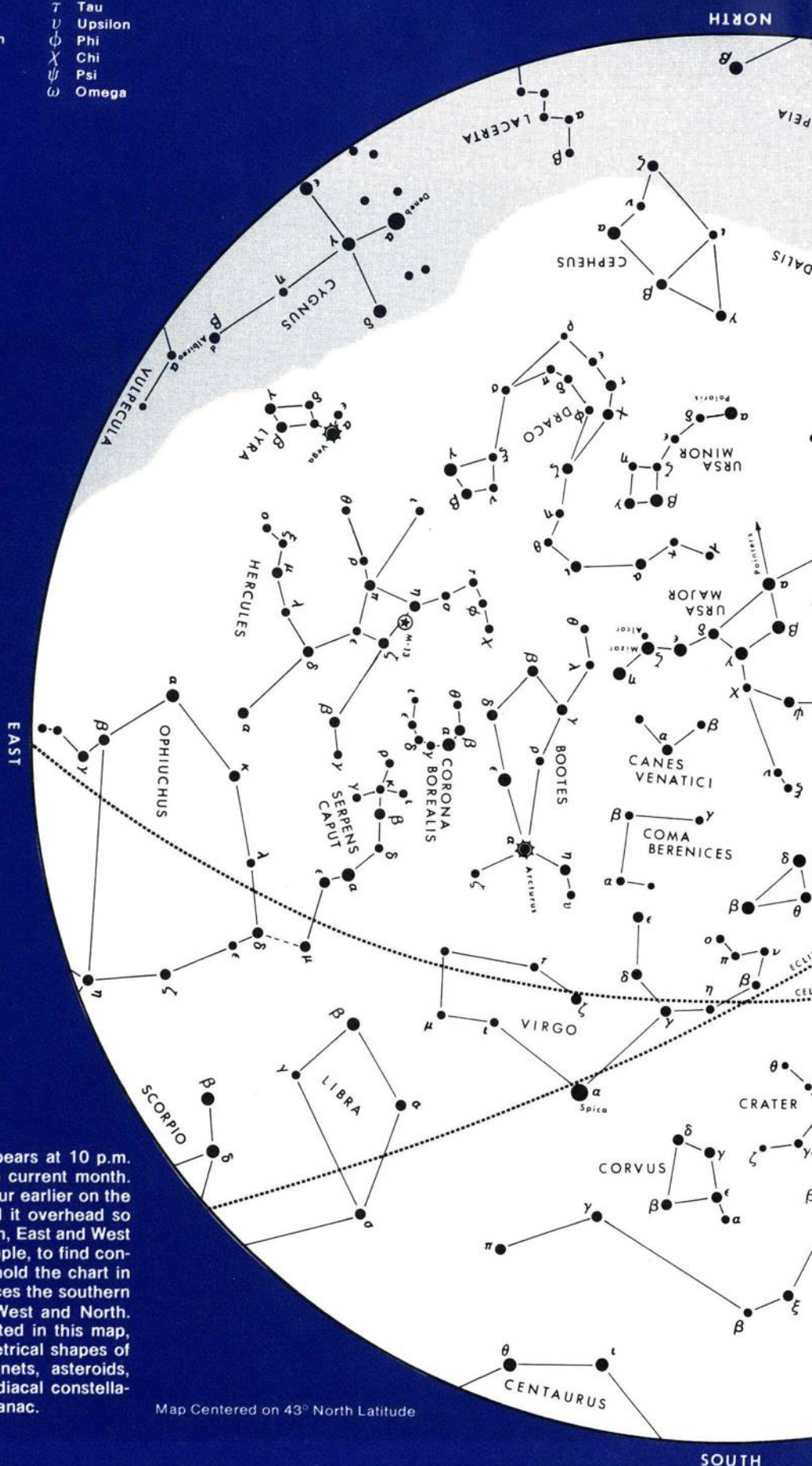
- Zero
- First
- Second
- Third
- Fourth
- Fifth

OBJECTS

- Open Clusters
- Globular Clusters
- Diffuse Nebulae
- Galaxies
- Double Stars
- Variable Stars

Star Dome approximates the sky as it appears at 10 p.m. Local Daylight Time on the first day of the current month. The same constellations are visible one hour earlier on the 15th. To use this constellation finder, hold it overhead so the compass points line up with North, South, East and West in your backyard or viewing area. For example, to find constellations in the southern part of the sky hold the chart in front of you so the South compass point faces the southern horizon. Repeat this procedure for East, West and North. Since only the brighter stars are represented in this map, you should be able to trace out the geometrical shapes of the constellations with ease. To find planets, asteroids, etc., visible among the current month's zodiacal constellations, refer to the planet finder in Sky Almanac.

Map Centered on 43° North Latitude



STAR DOME



Map by Raymond G. Couthie

On some primeval hilltop perhaps a million years ago, the first man raised his eyes to the sky and wondered. The same curiosity that has sparked man's science and philosophy has often been turned to the flickering lights of the night-time sky.

Stars were, at first, curious lights. But night after night, with the same stars passing in review, came the realization that the stars were fixed like pinholes in a giant velvet blanket. For each season certain familiar stars became important to our ancestors as the seasonal cycle of planting, growth and harvesting became a part of civilized culture. Yet somewhere back in the mists of prehistory, there was — and still is — a mental urge to organize the stars into patterns that would come down to us as the constellations.

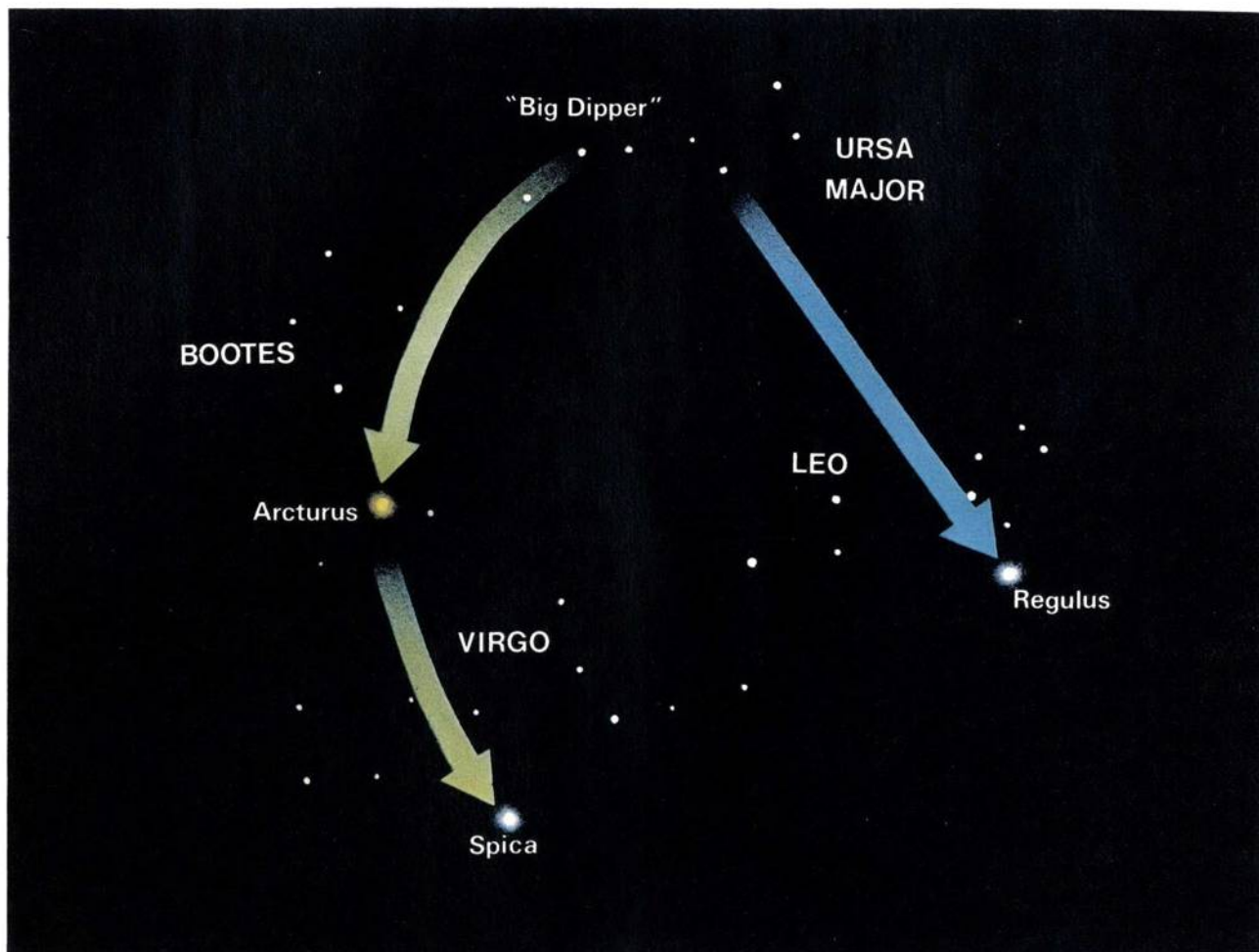
The constellation that is overhead on these warm spring evenings has been known since antiquity as the great bear, Ursa Major. You will look in vain for a resemblance to a bear in this figure. Modern man, seeking more descriptive terms, has called the brightest part of the bear the Big Dipper.

In spring skies, the Big Dipper is the most important star grouping. It's not properly a constellation, but a grouping that has proven useful to both the beginning sky gazer and the experienced observer alike. Now that Orion, the signpost of the winter sky, is no longer visible, the Big Dipper provides the same function that Orion did earlier this year: it acts as a pointer. In fact it serves as a number of pointers.

The main pointing function is indicated on the chart. The two stars at the end of the Dipper's bowl, opposite the handle, point out the open end of the bowl to Polaris, the North Star. The Big Dipper is visible from most of the United States for the entire year. The north identification function is really only the beginning of its usefulness. The diagram on the next page shows its additional functions.

Gamma and Delta, the two stars of the bowl nearest the handle, point down (or south) to Regulus, the brightest star in the zodiacal constellation Leo.

The curving handle of the Big Dipper provides the third major pointing function. Extending the curve of the handle takes us eventually to the brilliant yellow first magnitude star Arcturus (arc-TOUR-us) in the constellation Bootes (bow-OH-teez), the Herdsman. Continuing the



curve suggested by the handle past Arcturus we eventually end at another brilliant star — this time the blue-white Spica (SPY-ka) or Alpha in the zodiacal constellation Virgo.

The difference in color between Arcturus (magnitude -0.1) and Spica (+0.9) is easily seen once you look for it. Arcturus is the second brightest star in the sky for anyone living north of Los Angeles, Oklahoma City or Atlanta. (From these cities and south, the -0.9 magnitude star Canopus can be seen each winter.)

At a distance of 36 light-years, Arcturus is the nearest so-called “giant” star. By looking at it there is certainly no way of determining any of the characteristics of Arcturus (or any other star for that matter). Even a large telescope will show nothing more than a brilliant point of light. It has taken years of spectroscopic analysis and theoretical astrophysics to calculate that Arcturus is actually 4 times as massive and 25 times the diameter of the sun, and it shines 115 times more brightly.

Arcturus is a renegade star from a zone called the “halo”. The halo is the huge region that surrounds the main disk of the Milky Way galaxy. It contains relatively few stars compared to the spiral arms where we are located. Arcturus

is currently passing through our part of the spiral arm. Right now it is very close to its nearest approach to our solar system. In half a million years it will be below naked eye visibility in the constellation Hydra.

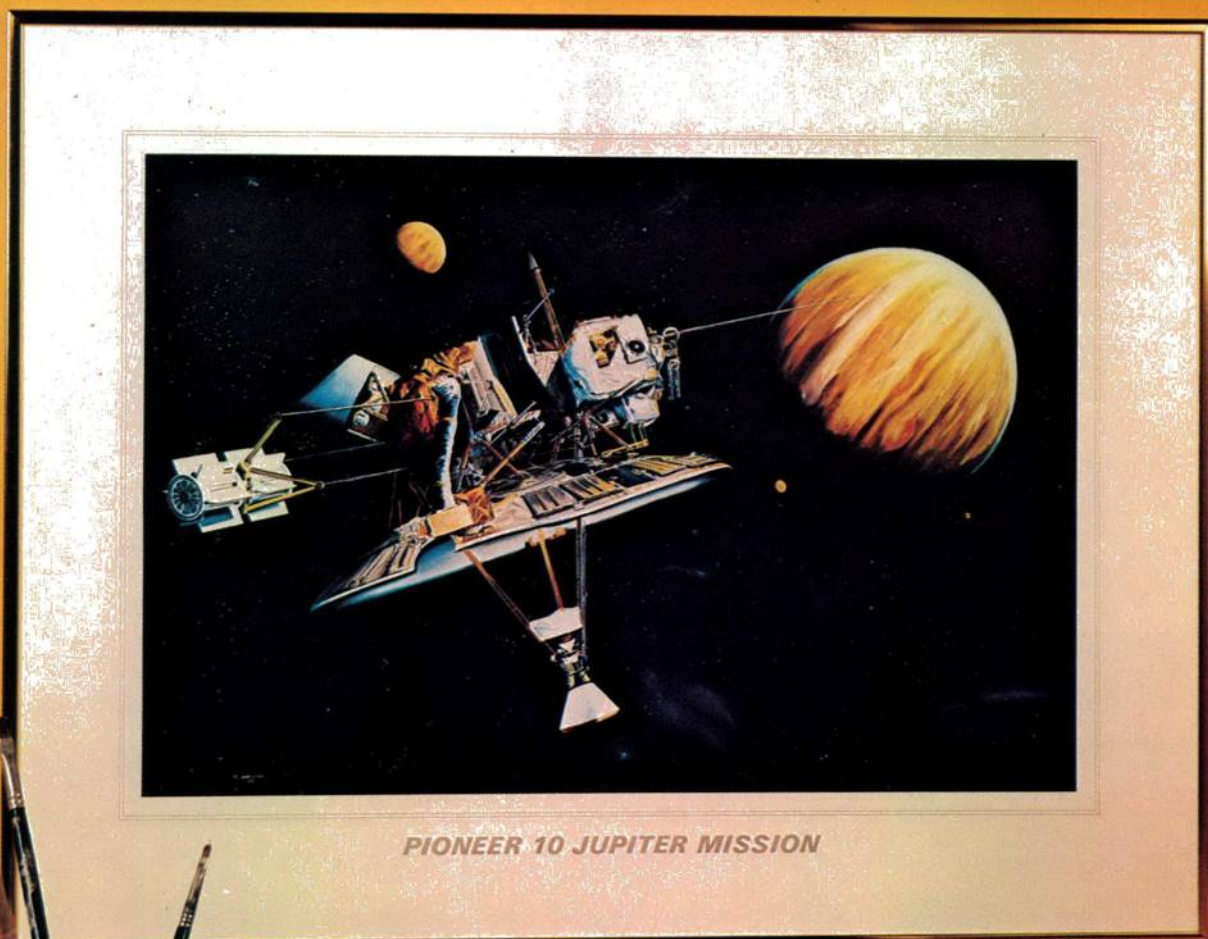
Arcturus is Greek for “the bear keeper” and may at one time have been the name for the entire constellation Bootes. The story is that Bootes was to make sure that Ursa Major, the great bear, kept circling the pole star. In the 17th century two hunting dogs (Canes Venatici) were added to help Bootes keep Ursa Major in line.

Although in Greek Bootes means “the herdsman”, the most famous legend surrounding him suggests that he was actually Icarius, a vineyard owner. One day he took the god Bacchus on a tour of his vineyards and Bacchus was thrilled. In return the god taught Icarius how to make wine from grapes. A lavish party ensued once the new liquid was tasted, followed by everyone falling asleep.

But the story has a bad ending. Icarius' friends awoke and, accusing him of poisoning them, they killed him. For this misfortune the gods placed him in the sky with his wife (today the constellation Virgo) and his hunting dogs (Canes Venatici). 🐾

Pioneer 10 Jupiter Mission

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Pioneer 10's encounter with the planet Jupiter marks a milestone in America's exploration of space. And to commemorate this historic event, John W. Clark, an upcoming space artist, painted an original oil portrait of the encounter with Jupiter. The Pioneer 10 painting was first used as a two page spread to lead off ASTRONOMY's feature "Encounter with Jupiter" in the February issue. And it not only accurately depicts in color all the detail in the Pioneer 10 spacecraft but also the detail and color of the planet Jupiter.

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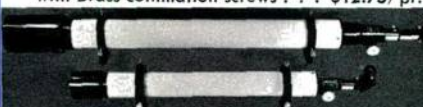
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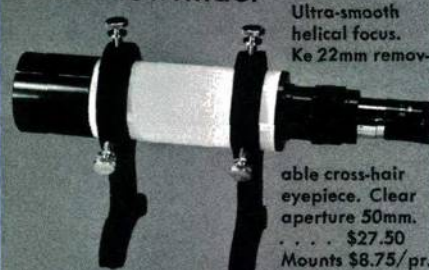
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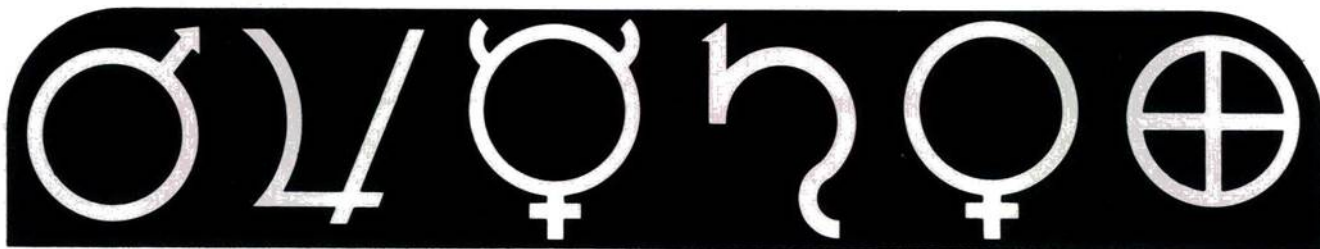
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Mercury and Saturn Brighten May

Two unlikely planetary twins, Saturn and Mercury, punctuate an otherwise planet-poor sky on May evenings. Since we have been watching Saturn all winter, the planet of interest now is Mercury.

Mercury

Mercury is almost always nestled in the sun's glare, its tight orbit never allowing the solar sys-

tem's smallest planet to be easily seen from more distant Earth.

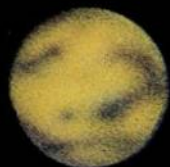
To locate Mercury as it swings to the eastern side of its orbit as seen from Earth, keep watching Saturn (now low in the west below Castor and Pollux) as it descends into the evening twilight. Around May 25 Saturn will be joined by Mercury. You should see Mercury shining about as bright as Saturn below and to the right of the ringed planet. Mercury will be eight degrees from Saturn on the

SATELLITE SHADOWS ON JUPITER

Date	Satellite	Transit begins (EDT)	Transit ends (EDT)
May 18	4	3:58 a.m.	8:20 a.m.
28	1	2:10 a.m.	4:25 a.m.
30	2	12:35 a.m.	3:28 a.m.
June 1	3	3:22 a.m.	6:53 a.m.

1 = Io
2 = Europa

3 = Ganymede
4 = Callisto



(A) Mercury

May 1
R.A. 2h24m
Dia. 5.0"
Mag. -1.6

(B) Mercury

May 15
R.A. 4h23m
Dia. 5.5"
Mag. -1.0



(M) Mars

May 1 15
R.A. 6h31m 7h08m
Dec. +24°45' +24°00'
Dia. 4.7" 4.4"
Mag. +1.7 +1.8



(C) Ceres

May 1 15
R.A. 22h34m 22h50m
Dec. -17°41' -16°58'
Mag. 8.3 8.2



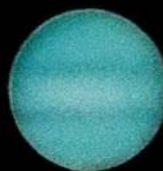
SUN

The sun is within the stippled zone throughout the month. Planets and stars near this area are not easily seen.



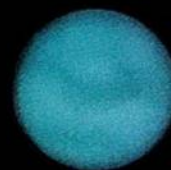
(S) Saturn

May 1 15
R.A. 6h05m 6h12m
Dec. +22°44' +22°45'
Dia. 15.5 15.2
Mag. +0.3 +0.3



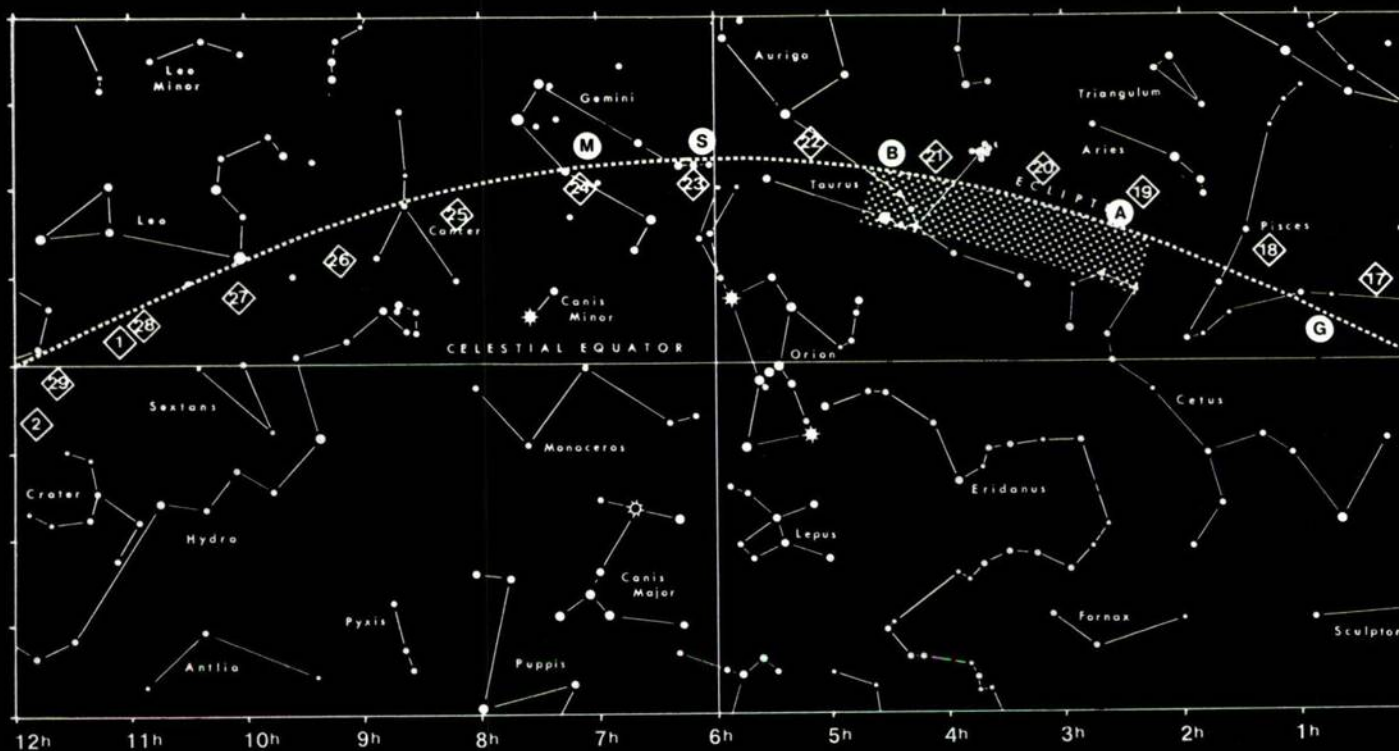
(U) Uranus

May 1 15
R.A. 13h34m 13h32m
Dec. -9°09m -8°57m
Dia. 4.0" 4.0"
Mag. +5.7 +5.7



(N) Neptune

May 1 15
R.A. 16h30m 16h29m
Dec. -20°11' -20°08'
Dia. 2.5" 2.5"
Mag. +7.7 +7.7



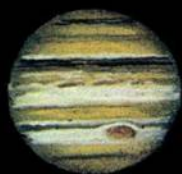
Map by Raymond G. Couteur

The chart shows the positions of the moon, planets and brightest asteroids for the current month. Letters within the circles correspond to the letters beside each object in the data section above the map. Additional information about each object is given there. R.A. = right ascension and DEC. = declination, the two coordinates used to locate astronomical objects. The general coordinate system is indicated around the edge of the map. MAG. = magnitude, a



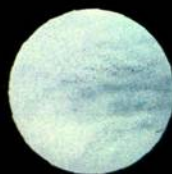
Vesta

May	1	15
R.A.	12h33m	12h29m
Dec.	+9°13'	+8°38m
Mag.	5.9	6.0



Jupiter

May	1	15
R.A.	22h53m	23h02m
Dec.	-8°08'	-7°19'
Dia.	33.8	35.0
Mag.	-1.7	-1.8



Venus

May	1	
R.A.	23h50m	
Dec.	-2°18'	
Dia.	18.7"	
Mag.	-3.8	

Venus

May	15
R.A.	0h49m
Dec.	+3°17'
Dia.	16.7"
Mag.	-3.6



Pluto

May	1	15
R.A.	12h43m	12h42m
Dec.	+13°59'	+14°01'
Mag.	+14	+14



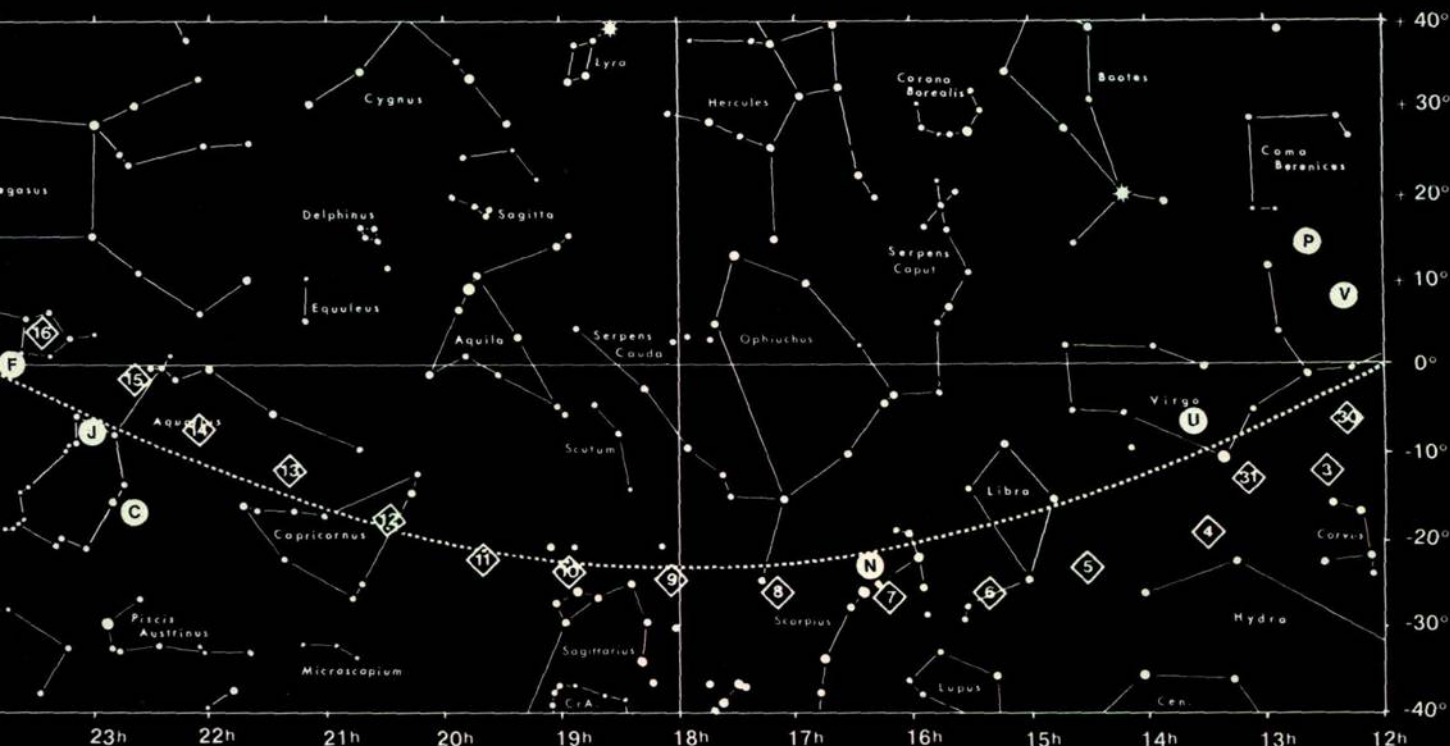
First Quarter
May 28



Full Moon
May 6



Last Quarter
May 14



Artwork by Victor Costanzo

measurement of the object's brightness. (The minus magnitudes indicate very bright planets.) DIA. = the planet's apparent diameter in seconds of arc. The diamonds with numbers within them indicate the position of the moon for each day of the month; the numbers correspond to the dates. Positions of the planets are for the 15th of the month except for Mercury and Venus which are shown on both the 1st and 15th.

25th; about four degrees to the lower right on the 29th, and only two degrees to the right on June 1. During this time Mercury will fade from magnitude -0.3 to +0.5 (compared to Saturn's +0.3). Most observers think the color of the two planets is the same — yellowish-white. This will be an interesting time to check.

For telescope users, the phase of Mercury will be visible in three inch or larger instruments. On the 22nd the small planet will have a 66 percent gibbous appearance with a diameter of only 6.2 seconds. Easier to distinguish will be the 53 per-

cent phase, 7.0 seconds in diameter on the 27th. By June 1 the planet's phase has decreased to 42 percent while the diameter is up to 7.7 seconds. Compare that to the width of Saturn's rings, 37 seconds on June 1.

Through the telescope Saturn and Mercury will be strangely different. Mercury, a tiny brilliant disk, contrasts sharply with Saturn's washed-out appearance in the twilight sky. Saturn only looks good in a dark sky because its surface brightness is quite low due to its distance from the sun. Mercury, 30 times closer to our star than Saturn, receives about 1,000 times the intensity of sunlight and thus reflects vastly more light into space.

The best time to observe Mercury telescopically is 30 to 50 minutes after sunset before the small planet is too close to horizon turbulence. Your telescope's finderscope will be useful for finding it (and Saturn) at that time.

For unaided eye observers look for the two planets low in the west between 45 and 70 minutes after sunset. The moon is near Saturn on the evening of the 23rd. Can anyone get a photo that evening that shows Mercury, Saturn and the moon?

SATELLITES OF JUPITER MAY					
1	1203	••●•	16	20134	•●•••
2	42013	••●••	17	1024	•●••
3	41302	••●••	18	34012	••●••
4	43012	••●••	19	34210	•••••
5	43210	••●••	20	43201	••●••
6	430	••●••	21	4032	••●••
7	40132	••●••	22	4103	••●••
8	41203	••●••	23	42013	••●••
9	24013	••●••	24	41023	••●••
10	1024	••●••	25	43012	••●••
11	30124	••●••	26	31240	•••••
12	32104	••●••	27	32014	••●••
13	3204	••●••	28	10324	••●••
14	0324	••●••	29	0234	••●••
15	1034	••●••	30	20134	••●••
			31	1034	••●••

The four major satellites of Jupiter orbit the giant planet in periods ranging from just under 2 days to 17 days. They can be seen to change position from night to night. Sometimes their motions become evident after only a few minutes' observation. Only a small telescope is required to detect all four of the satellites and several can frequently be seen in rigidly held binoculars. This table shows the approximate positions of the moons at about midnight (EDT) on the evenings indicated. First column on the left shows the date. Second column of numbers identifies the moons and their positions relative to Jupiter's disk. (1 = Io; 2 = Europa; 3 = Ganymede; 4 = Callisto, and 0 = Jupiter's disk.) The third column approximates a telescopic view of the satellites' positions. The orientation of the satellites is shown inverted as seen in a standard astronomical telescope.

Saturn

Except for its convenient position for locating Mercury, the solar system's showpiece planet now low in the west after sunset is not in good observing position. On May 1 it is 895 million miles from Earth, near the far side of its orbit. By month's end it is even farther at 923 million miles.

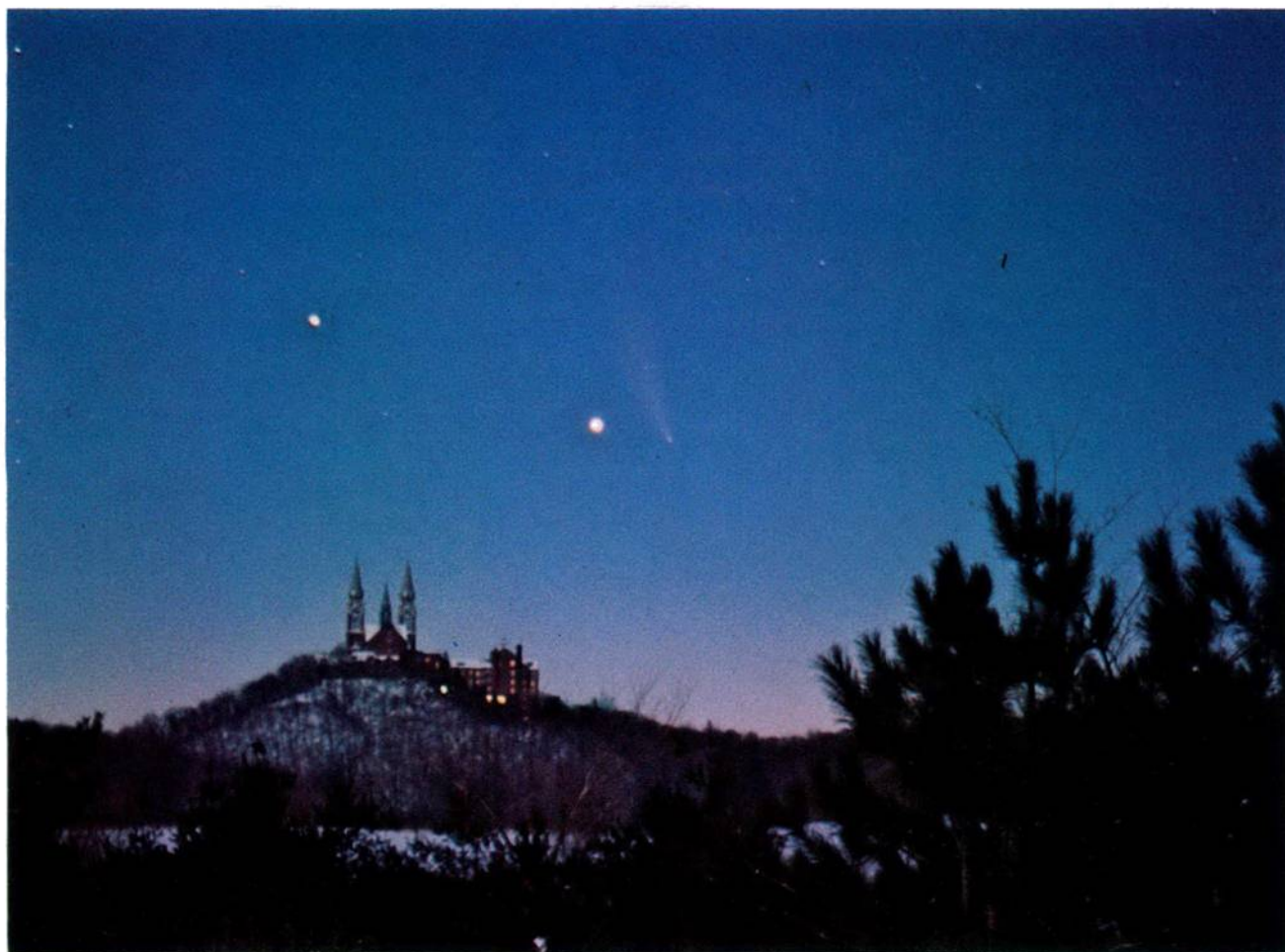
Mars

Low in the west below Castor and Pollux in Gemini, but closer to them than Saturn, is the faint and distant Mars. During the month it fades from magnitude +1.7 to +1.9 as it swings from 185 to 206 million miles from Earth on the far side of its orbit. Its tiny disk shrivels from 4.7 to 4.2 seconds of arc in apparent diameter during May.

Jupiter

Although awkward for most observers' schedules, Jupiter is worth observing if you are up after 1 a.m. later in the month as it rises shortly thereafter in the southeast. It is unmistakable — a brilliant "star" at magnitude -1.8 in the faint constellation Aquarius.

Through a small telescope the planet's four large moons are visible as shown in the chart on



Jan. 6, 1974

Photograph © by William E. Brown

In one of those rare moments of tranquil beauty, Comet Kohoutek was captured as it hovered over this Wisconsin

landscape. The scene is a 10 second exposure on Fugichrome R-100 with a 55mm f/1.9 lens.

page 40 . The moon's shadows on the disk of Jupiter are a fascinating sight. Watch for them at the times indicated in the table.

Venus

For the next five months Venus will be visible for over an hour before sunrise in the southeast. Shining at magnitude -3.6 this month it exceeds even brilliant Jupiter which is well above it in the morning sky. The crescent Venus — a beautiful sight in any small telescope — is now gone for many months. As the planet swings away from Earth, its phase increases from 61 to 73 percent while its apparent diameter diminishes from 18.7 to 15.0 seconds during the month. Distance from Earth is 84 million miles on the 1st and 104 on the 31st.

Neptune

On the 30th the planet Neptune is nearest

Earth at a staggering 2.72 billion miles. Even sunlight takes over four hours to reach this distant world which appears as a tiny 2.5 second wide disk in a four inch or larger telescope.

More Chart Changes

In response to readers' requests the planet identification letters on the planet finder chart now correspond to the first letter in the planet's name where possible. For Uranus hunters the chart on page 52 in the April issue was printed inverted for telescopic use. Turn the page over for binocular use.

Meteors

The Eta Aquarid meteor shower, due on May 5 this year, usually provides 20 meteors per hour for the vigilant observer in early morning hours. But forget it for this year; the full moon will make any attempt a waste of time. Its light will cut the observable meteor rate to two or three per hour. ☛



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ASTRO-NEWS

Latest News From the World of Astronomy

Pioneer 11 To Visit Saturn

The longest, most exotic space mission ever planned — a voyage to the ringed planet Saturn — is already underway.

Pioneer 11, the twin of the craft that took close-up photos of Jupiter late last year, was launched without fanfare in Feb. 1973. Ever since, it has been hurtling toward a December rendezvous with Jupiter.

It was to follow its predecessor, Pioneer 10, on a rapid swing by the solar system's largest planet, whose immense gravity would fling it on a multibillion year voyage to the stars.

But with the confidence of the successful Pioneer 10 mission behind them, scientists at NASA's Ames Research Center in California have planned a daring twist to the Pioneer 11 flight plan. The 570 pound robot craft will now swoop to within 26,000 miles of the turbulent clouds of Jupiter — three times closer than Pioneer 10.

Pioneer 10's delicate experiment package was almost destroyed by an intense zone of trapped radiation enshrouding Jupiter. Although Pioneer 11 will travel nearer to Jupiter, it will approach from below Jupiter's south pole and then be pulled rapidly upward by the giant planet's enormous gravity, intersecting Jupiter's equatorial plane at an angle of 55 degrees. The spacecraft will then exit from Jupiter, well above the planet's north pole.

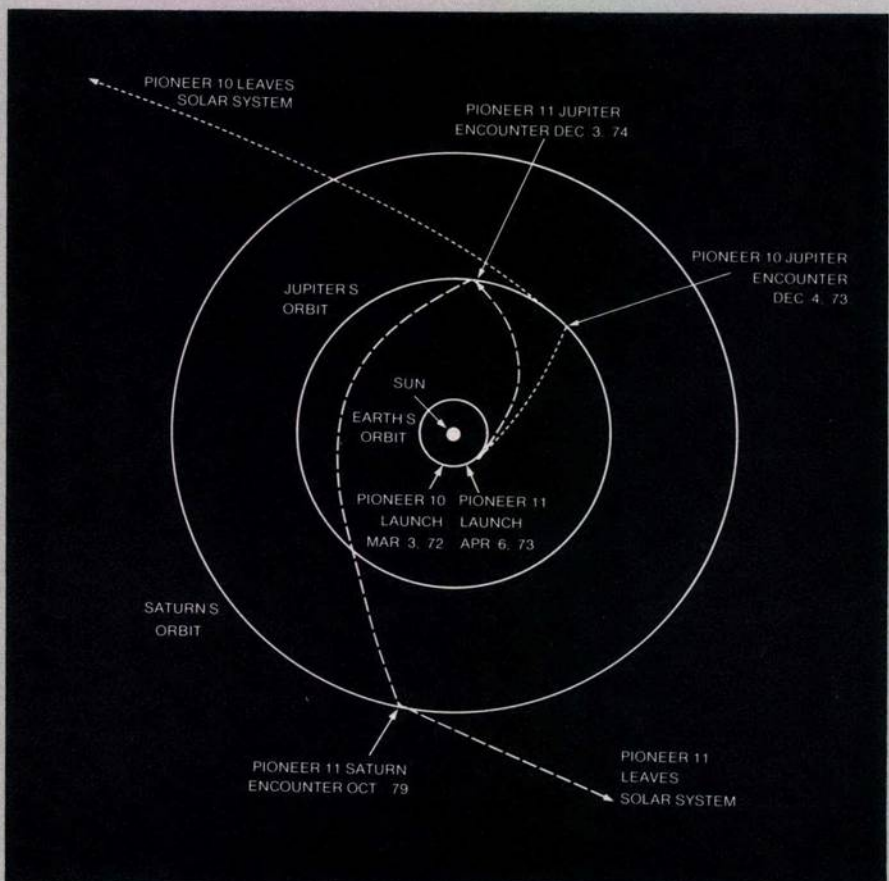
The close approach to Jupiter will speed up the spacecraft to 110,000 m.p.h., relative to the planet. This speed, plus the high angle of approach to the disklike radiation belts, should bring Pioneer through Jupiter's zone of intense radiation very rapidly. It is hoped that this will reduce the cumulative radiation dose to spacecraft systems to acceptable limits.

After circling almost the entire planet the space voyager will boomerang back toward Earth on a five year journey that will carry it up to 100 million miles above the disk shaped solar system. Slowed by the sun's gravity the

craft will zero in on Saturn in Oct. 1979.

The Saturn option was one of several that had been under consideration for some time. Another plan was to send the craft on a polar pass around Jupiter and then on a trajectory far above the

continued on page 45



Pioneer 11, now on its way to Jupiter, has had its trajectory adjusted to carry it around Jupiter and back over a vast area of the solar system to an eventual encounter with Saturn in 1979. After a Saturn flyby it will plunge into deep space just as Pioneer 10 did after its historic swing by Jupiter in 1973.

Safe Crossing of Asteroid Zone

Pioneer 11 has completed its seven month journey through the asteroid belt proving Pioneer 10's safe passage wasn't just good luck. The instruments aboard the spacecraft counted about the same number of dust particles in the 80 million mile wide region between Mars and Jupiter as Pioneer 10 counted earlier.

Pioneer 11's asteroid/meteoroid detector reported 250 sightings since launch almost a year ago. About half the observations were in the asteroid belt. (Pioneer 10 recorded 123 sightings in the asteroid belt between Aug. 15, 1972, and Feb. 15, 1973 according to Dr. Robert K. Soberman, principal investigator.)

The meteoroid detector aboard Pioneer 11 recorded seven penetrations by dust particles in the asteroid belt. That compares with 13 hits between Earth and the belt's inner edge. (Pioneer 10's meteoroid detector reported 17 hits in the asteroid belt, according to Dr. William H. Kinard, principal investigator.)

Soberman's experiment consisted of four telescopes that saw light reflected from nearby dust particles. Kinard's experiment consisted of 234 gas filled metal pressure cells that recorded impacts by dust particles.

Before Pioneer 10 cleared the asteroid belt, many scientists feared dust there was so thick that no spacecraft could survive. Even after Pioneer 10 got through, some believed it a lucky crossing. Pioneer 11 confirms that dust in the asteroid belt is much lighter than anyone suspected, eliminating what was thought to be the chief danger of the asteroid belt — "high velocity projectiles". These small, very high speed particles might penetrate spacecraft and do serious damage.

Particles in the center of the belt orbit the sun at about 38,000 m.p.h. This is fast enough for a meteoroid with a mass of 1/1000 of a gram to penetrate one centimeter (about 3/8 of an inch) of aluminum. However, most of the particles seen by Pioneers 10 and 11 were smaller than 1/1000 gram, and total numbers of particles seen were far lower than many predictions.

The doughnut shaped asteroid zone is believed to be 50 million miles thick, so spacecraft cannot easily fly over or under it. Asteroids are small bodies, most of them less than a mile in diameter, that travel around the sun like small planets. Several hundred have been identified and named but thousands more exist. ☛



Site Chosen for Infrared Telescope

The world's largest infrared telescope is to be built and installed on Mauna Kea, the highest mountain in Hawaii. The site was chosen for the \$6 million facility after a survey of several potential sites in Hawaii, Arizona and Mexico's Baja California peninsula. The 120 inch telescope will be operated by the University of Hawaii for the National Aeronautics and Space Administration.

The telescope will be used primarily to provide supporting and complementary data to NASA's planetary exploration programs. Infrared observations of the outer planets and their satellites can provide basic data on the temperatures and surface characteristics of these bodies. Such information is desired by early 1977 — prior to the launch of Mariner 11 — to optimize planning for that spacecraft's encounters with Jupiter and Saturn.

An infrared telescope, while similar in general appearance to a conventional optical telescope, is uniquely designed to eliminate the effect of undesired

infrared radiation, either from the sky or from the telescope itself. Construction of a large infrared telescope has been one of the top priority items listed by the National Academy of Sciences in a recent study, "Astronomy and Astrophysics for the 1970's". Completion of construction is planned for mid-1976, with the first observations in early 1977.

The recent growth of infrared astronomy has created large demands on existing telescopes, most of which are neither at the best sites nor properly designed for good infrared viewing. Mauna Kea, nearly 14,000 feet above sea level, is the present home of a NASA funded 88 inch telescope. A 144 inch telescope is also to be built there by the National Research Council of Canada, Centre National de la Recherche Scientifique (CNRS) of France, and the University of Hawaii. The high altitude and superb atmospheric conditions on Mauna Kea are ideal for both regular optical and infrared observations. ☛

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ASTRONOMY

It's Not A Silvery Moon

Moonlight would be about four times brighter than it is, according to a Cornell University lunar scientist, if it weren't for the presence of tiny quantities of "extra iron" on the surface of each grain of lunar dust. Speaking at the fifth annual Houston Lunar Conference, Thomas Gold said that an iron-rich coating around grains of lunar dust was the answer to the long-standing puzzle: why is the moon so dark?

"The appearance of the moon in the sky would suggest that the surface is silvery white," Gold said, "but this is

not so. One is misled because one does not have another equally illuminated object for comparison. In reality, the surface of the moon is a very dark gray."

The darkness puzzle hinged on the discrepancy between two pieces of well documented knowledge: 1) that the moon's surface is covered with a fine rock powder, and 2) that almost all rocks — lunar ones included — become very light when ground up to the consistency of the lunar soil. For several years now, the Cornell Lunar Laboratory, under Gold's direction, has been trying to determine the existence of

some special circumstance which would make the powder appear dark.

Gold, director of Cornell's Center for Radiophysics and Space Research, had suggested as early as 1955 that the surface of the moon was a powder, and that each individual dust grain might be coated with a very thin, dark layer (only a few atomic dimensions thick) giving the moon its somber coloring. His idea was that some effect of the sun would cause such a surface action.

Gold's hypothesis was corroborated in 1964, when Bruce Hapke of the Cornell Lunar Laboratory demonstrated how fine rock powders exposed to a laboratory simulation of the solar wind became as dark as the lunar surface. (The solar wind, which is known to strike the moon, is a stream of charged particles accompanied by a magnetic field flowing continuously out from the sun at speeds of about 248 miles per second.) Although the evidence for the effect was convincing, the composition of the thin, dark coating was still unknown. Gold said that the difficulty in determining the nature of the coating persisted even after the Apollo missions made lunar materials available for direct study.

Two of Gold's research associates reported at the conference that the surface of each grain of lunar dust was greatly enriched in iron, compared to the iron content in the bulk material. Three times as much iron in the surface layers of each grain as in the interior was detected.

Interpreting the significance of the new findings, Gold said that in each sample the iron enrichment matched the degree of extra darkening that could be measured. "Darkness and extra surface iron are clearly associated," he concluded, citing the solar wind effect that had previously been observed as the most likely cause of the surface action on the moon.

Gold said that the light and dark areas we see, like the famous face of the "man in the moon", are created to a great degree by the amount of surface treatment that the material in each area has received.

"A longer surface exposure will result in a darker surface," he said. "The regions that are slightly lighter must be the ones that have not been exposed quite so long, and these are usually the mountains. The flat plains, which usually are darker, must be the areas of longest exposure."

Pioneer 11 continued from page 43

ecliptic (the plane of Earth's orbit around the sun).

Pioneers 10 and 11 passed without incident through the asteroid zone between Mars and Jupiter on their outbound journeys (see companion article). Pioneer 11 will only graze the top of the zone during its flight to Saturn. In any case the asteroids do not pose a hazard to future missions to the outer planets.

If successful, this will mark the longest interplanetary spaceflight ever — a total distance of 1.5 billion miles. (That's about 3,000 times farther than a typical Apollo moon mission.)

Pioneer 10, meanwhile, is still sending scientific information to Earth as it continues its voyage to and beyond the orbit of Pluto, the outermost planet of the solar system.

Pioneer 11 will reach Saturn only two years before a pair of Mariner spacecraft, which will be launched toward Jupiter in 1977. The Mariners will investigate Jupiter in 1979 and then be flung on a much shorter path toward Saturn for encounter in 1981. The two giant planets will be in much better alignment for dual missions late in this decade.

If it's still working, Pioneer 11 will send back color pictures of Saturn and its rings. We may finally learn the composition of the rings — especially if Pioneer 11 is sacrificed in a suicide plunge into the rings.

The rings are thought to consist of billions of boulder sized chunks of snow or snow-covered rock. Each one has its own orbit around Saturn, traveling at an average of 50,000 m.p.h.

The density of the rings is not known so a flight through them is an intriguing, although unlikely, alternative. Pioneer 10 will probably be targeted for a safe distance outside the rings to enable measurement of Saturn's magnetic environment, believed to be less than 1/10 as intense as Jupiter's.

After passing Saturn the spacecraft will be flung on an endless trek through the galaxy. Attached to Pioneer 11 is a plaque telling, in symbolic terms, of the vehicle's origin and the beings that constructed it. The emptiness of space will preserve both the craft and the plaque for millions of years — long enough for some advanced civilization to perhaps stumble on it and examine an artifact of a primitive culture. ☛

Mercury Moon Becomes Star

A faint star in the constellation Corvus made headlines around the world on April 1 when it was mistaken for a newly discovered moon of the planet Mercury.

When Mariner 10 flew past the innermost planet the craft's ultraviolet spectrometer picked up an object seemingly in orbit about the planet. However the spacecraft's television cameras failed to reveal any trace of the object and renewed analysis identified it as the star 31 Crater. This extremely hot star, similar in many ways to Bellatrix (Gamma Orionis), was detected as it "passed behind" Mercury.

Maybe it was Mariner 10's way of saying April fool. ☛

Soviet Mars Exploration Fails

A flotilla of four robot space vehicles launched from the Soviet Union last summer has failed to accomplish its primary goal — transmission of live television pictures from the surface of Mars.

Two of the craft, Mars 4 and 5, were intended to orbit the planet in late Feb. 1974 but Mars 4's braking rockets malfunctioned and only Mars 5 actually achieved orbit. Swinging around Mars in a 25 hour orbit, Mars 5 could have conceivably relayed pictures from Mars 6 and 7, destined to eject capsules to land on the sands of the dusty planet in mid-March. But it was not to be.

Mars 7 reached the planet on March 9 and released a descent capsule

but a malfunction caused it to miss Mars by 780 miles. Mars 7 did however drop its landing capsule at the appropriate time as it hurtled past the planet on March 12.

During descent by parachute through the thin Martian atmosphere the capsule's instruments reported temperatures and information on atmospheric composition. Then, about five minutes before scheduled landing, all transmissions ceased. Nothing has been heard since.

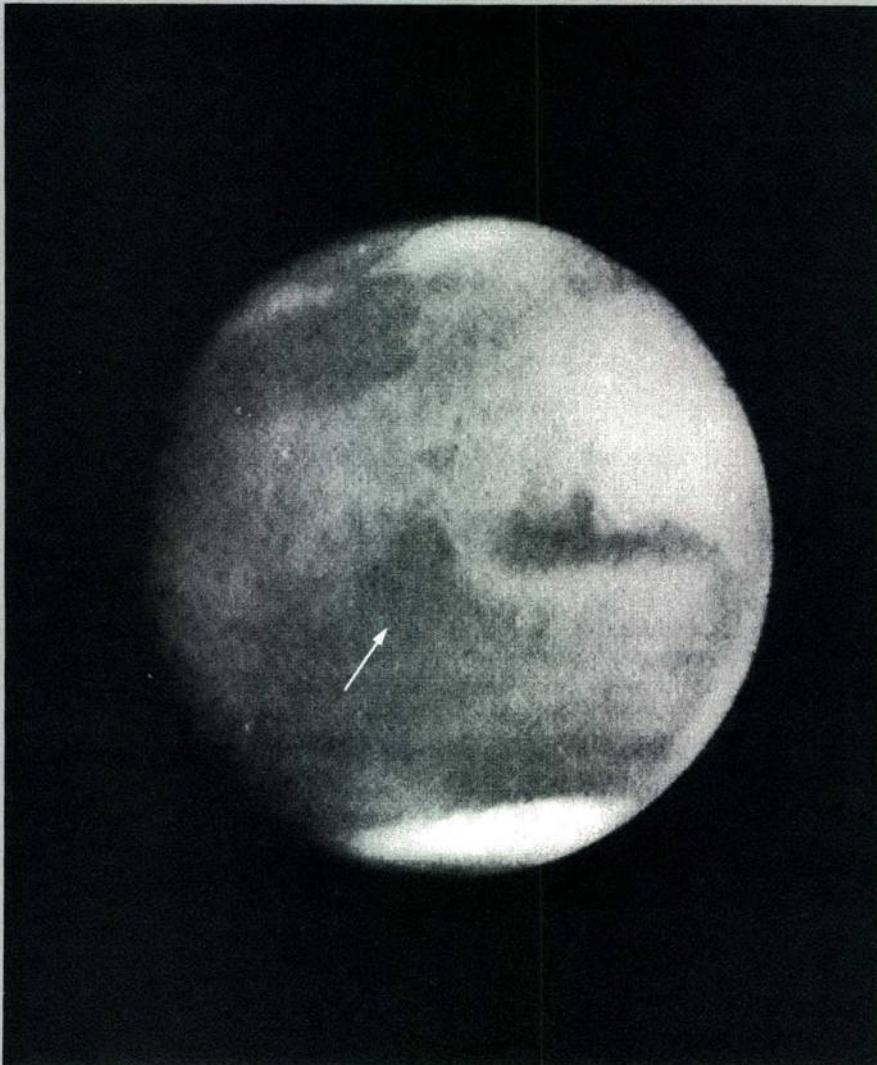
Of the four vehicles only Mars 5 is still functioning — a setback for Soviet unmanned space exploration and an acute disappointment for all interested onlookers. The Mars 5 may provide full color pictures of the planet from

orbit. It is equipped with two cameras of similar resolution to those on Mariner 9.

However, our first glimpse of the Martian surface will now have to wait for the cameras of Viking — the United States' sophisticated life searching landing mission of 1976. Viking is the most costly unmanned space venture ever mounted by the U.S. The one billion dollar program involves two Mars orbiters that will release landing vehicles.

The American Mars program contrasts sharply with that of the Soviet Union. Of six U.S. probes to the red planet, four have been remarkable successes. The discoveries of Mariner 9 alone have revolutionized our concept of Mars (see articles by Carl Sagan in this and previous issues).

By contrast the Soviets have launched 13 spacecraft toward the planet. Prior to the recent series only two worked — Mars 2 and Mars 3. Both spacecraft reached Mars in late 1971 and released landing capsules, one of which apparently intentionally crashed on the planet. The other survived a semisoft landing on the Martian surface. This surviving surface vehicle — the first functioning craft ever to land on Mars — began to transmit television pictures of the Martian surface. But its transmissions terminated after only 20 seconds for reasons still not clearly understood by either Soviet or U.S. scientists. Each landing probe had an orbiting section which is still circling the planet. However, the information returned from the orbiters (in terms of photographs and other data from on-board sensors) was far less than that obtained from Mariner 9 which viewed Mars at the same time. 🐞

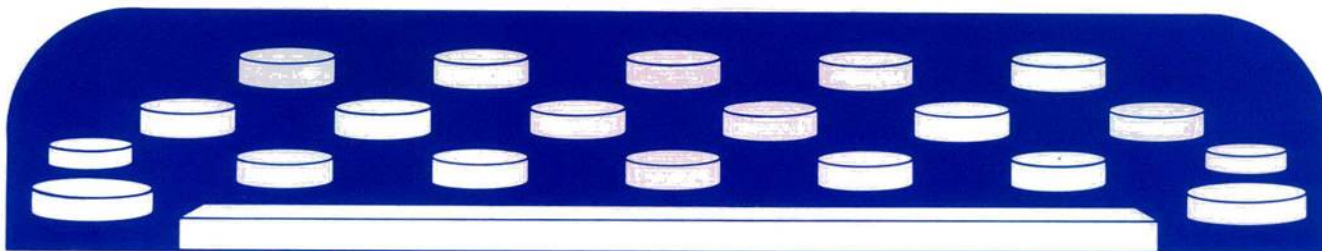


NASA Photograph

When the Soviet probe Mars 6 swept past the red planet on March 12 it ejected a capsule that landed in a region of Mars known as Mare Erythraeum (arrow). Unfortunately transmissions from the capsule ceased shortly before touchdown.

New Neutron Star Theory

According to a small item in the Waycross, Ga. *Journal-Herald* on Oct. 5, 1973, a neutron star "is a collapsed star consisting of immense numbers of densely packed pan-fried or broiled livers." 🐞



IN FOCUS

Sir / Recently I got into an incredibly ridiculous argument with a friend over a statement he made regarding a certain star which he called Octavius (spelling questionable). He ascertained that a cousin knowledgeable in the location of constellations and stars told him that this particular star moved visibly in an easterly direction and then set in the east. He said he had observed this while visiting his cousin in Colorado.

I then tried, for four hours, to explain why this was impossible: that Earth's rotation caused the stars to appear to move as they do westerly and although there are a few known stars which do move (Barnard's Star and others) they could not possibly be seen moving, especially eastward.

My question is: does a star named Octavius even exist, and if so can you give me its magnitude and flamsteed number and any other available information on it? I tried to find information on it at our local junior college but came up with nothing.

GREG HALCOMB
Redding, Calif.

Mr. Halcomb / Some people will believe anything! No, to our knowledge there is no star called Octavius and you shouldn't waste your time in further deliberations on this subject. We include it here as an example of long and largely fruitless arguments that pseudoscience spawns.

Sir / In going over my old astronomy books, I came across one in which the author lists the then proved nine moons of Saturn. He also lists a tenth, "Themis, whose existence has never been proved," discovered by W. Pickering in 1905. This was 61 years before A. Dollfus discovered Janus, during a period of edge-on rings (the only time Janus is visible). I also noticed that 61 years ago Saturn was also near edge-on. Could this be more than coincidence?

ROBIN K. deSANTOS
Columbus, Oh.

Mr. deSantos / Sorry, no coincidence involved. William Pickering's discovery of Themis is well documented. He observed it just beyond Titan where the faint moon Hyperion orbits. Hyperion was known to Pickering but Themis seems to be imaginary since it has not been seen since. Janus on the other hand is the nearest moon — just beyond the rings.

Sir / I enjoyed "In View of Vesta", but I have one question. In the 1971 **Information Please Almanac** I found the diameters and magnitudes listed for the asteroids to be different than in the table on page 43 of the March issue of **ASTRONOMY**. Which is correct?

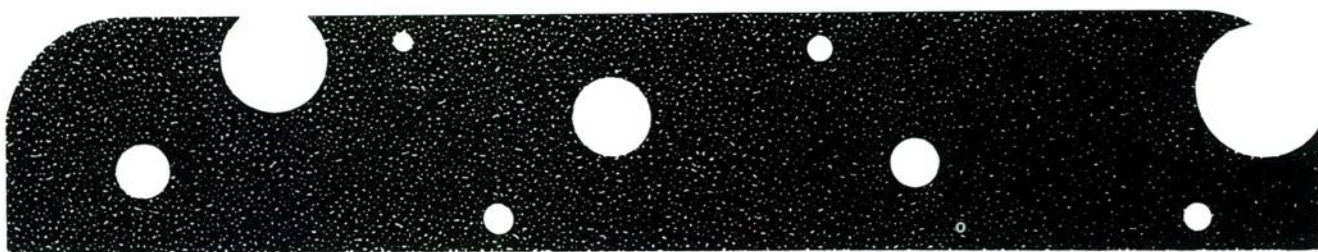
R. RAY BISCHER
Onaway, Mich.

Mr. Bischer / One reason ASTRONOMY exists is to provide the most up-to-date statistics and information available in a rapidly advancing science. Our figures in "In View of Vesta" are based on research conducted in 1972 and 1973.

Sir / Not to be paranoid, but if an advanced technological civilization exists in a neighboring stellar system (within a few hundred light-years) and if said civilization has plans for reconnoitering our solar system, then a clever way of doing so would be by means of a natural appearing comet such as Kohoutek! Note that Kohoutek was observed to have water and hydrogen cyanide in its vapor trails, the latter compound having never been seen before in comets. Granted that ice apparently constitutes most comets; it nonetheless could make an ideal shield for a "cometcraft". Water ice would be economical as a material; it would absorb radiation and meteorites; it would melt near the destination star and opportunely reveal the cometcraft's instruments for purposes of making observations. Hydrogen cyanide has been used as a disinfectant by man in his own space flights, which is possibly just another coincidence.

By its orbital path, Kohoutek certainly could have come from another stellar system. It is of course completely unfeasible for cometcrafts to travel at relativistic velocities; however, they might indeed travel at some 1/10 to 1/3 the velocity of light. Doing so, our nearest star neighbors could reach us in a few years. But it is not necessary to travel even that fast. A few thousand year's travel time (for an instrumental package) is nothing compared with the millions to billions of years involved in a civilization's lifetime.

WILLIAM S. JARNAGIN
Concord, Mass.



STELLAR FRONTIERS

Supernovae & Thunderstorms

by

Gerrit L. Verschuur

Thunderstorms and the lightning they generate have a direct bearing on the lives of most people on Earth. Many thousands die each year from lightning flashes. Thousands of costly forest fires the world over are ignited by lightning. But what causes the generation of electricity in the thunderclouds which gets released as the sudden lightning flashes? The answer to this question has puzzled man for a long time and it has enjoyed close attention ever since Benjamin Franklin made his pioneering experiments in measuring electrical fields in Earth's atmosphere. That was back in 1749, and we all have the mental picture of Franklin flying his kite into thunderclouds as he performed his experiments.

While many theories, all extremely complicated, have been proposed to explain the generation of the large electrical charge built up in thunderclouds, none meets with overwhelming

acceptance. According to the **Encyclopaedia Britannica**, "the mechanisms responsible for thunderstorm electricity are complicated". Several statements are made which do not allow us to form any clear picture and then we read, "...all these factors contribute to thunderstorm electricity". One used to reading between the lines of such statements would translate this as "no one really knows". Now however, a simple theory — one that can be demonstrated in the laboratory — has been proposed which elegantly explains not only thunderstorm electricity but also the normal electrical fields that exist in the atmosphere on a clear day.

Do supernovae and lightning have anything in common? Here artist Vic Costanzo mingles the Crab nebula — a supernova remnant — and an earthly lightning bolt in his symbolic interpretation of this mind boggling new theory.

Artwork by Victor Costanzo



COSTANZO

It is all because of supernovae! This is a slight exaggeration, but if it were not for supernovae we would have very few, if any, thunderstorms on Earth. And if the sun did not have flares, we would certainly have no thunderstorms at all. How does this all tie together?

In the Dec. 1973 issue of **Foundations of Physics**, Lars Wahlin, a physicist who has long been interested in thunderstorms, presented a brilliant new theory. His model for the generation of cloud electricity invokes the ionization produced in the lower atmosphere by cosmic rays.

Cosmic rays from outer space are known to reach the surface of Earth in large numbers. (Actually it is more strictly correct to say that secondary particles produced by cosmic rays reach the surface of Earth.)

The cosmic rays coming in from deep space are very high speed particles, mostly positively charged ions and protons (atoms which have had their electrons stripped from their orbits about the nuclei). The electrons are also flying through space at these near light speeds but are easily absorbed in the high atmosphere. But when a heavy cosmic ray strikes a molecule high in Earth's atmosphere it destroys the molecule and produces what is called a shower of smaller secondary particles, both positively and negatively charged. These can, in turn, do the same thing to other molecules lower in the atmosphere. The result is that the average air around us is full of negatively and positively charged ions all the time (several billion in the average living room).

The important point is that the negatively charged ions find it very easy to stick to any surface that they happen to come across, whereas the positive ions do not. And this is where the thundercloud comes in.

Thunderclouds have strong upward drafts within them. Indeed if there were no updrafts to start with, such as those produced on a hot day, the clouds would not develop. The updrafts carry the positive and negative ions upward, but the negative ions stick to the first surface they come to and these are the raindrops. However, the positive ions continue all the way to the top of the cloud. This means that the bottom of the cloud becomes negatively charged and the top becomes positively charged to create the enormous electrical charge differences between the top and bottom of the thundercloud. As a result, very large voltage differences are built up through the cloud that can only be relieved by lightning strokes. At the same time, opposite charges can be induced by the lower part of the cloud onto

the ground which can result in cloud-to-ground lightning.

Now, what about the supernovae? It turns out that most, if not all, of the cosmic rays that are producing the relevant ionization of atoms and molecules in Earth's atmosphere had their origin in stellar explosions. Some have their origin in solar flares — explosions on the sun. But cosmic rays from flares are not often observed to reach the surface of Earth, even indirectly. The flare associated particles have much lower energy than those from outer space and tend to be absorbed in the uppermost reaches of Earth's atmosphere. If there were no supernovae occurring, there would be few cosmic rays reaching Earth at all. The result: no thunderstorms. Another factor that influences the penetration of cosmic rays into the atmosphere is our planet's magnetic field which deflects the particles in their paths through space. If Earth had a much stronger magnetic field we would probably have fewer thunderstorms.

An interesting speculation at this point is that during a reversal of Earth's magnetic field there must be a situation where there is no magnetic field out in space to shield Earth from any particles. Perhaps there were very large numbers of thunderstorms during those periods. (The last reversal is known to have occurred 750,000 years ago.)

To trace this story to its source we have to explore the origin of cosmic ray particles in stellar explosions. We will ignore for a moment that other sources of cosmic rays might also exist; for example, exploding galaxies. This is still controversial to some extent. In any case the particles do originate at astronomical distances.

When a star explodes — for whatever reason — (producing what we call a supernova) it generates a tremendous amount of energy. Matter that once formed part of the outer layers of the star gets accelerated outward with incredible force. Magnetic fields are also carried out by the expanding shell which soon interacts with matter and magnetic fields in surrounding space. Since the magnetic field structures are far from uniform one can have even further acceleration of the particles by their interaction with the field lines. This is fairly well understood by astrophysicists. The material in the explosion is all ionized, which means that the expanding shell contains electrons stripped from their parent atoms leaving positively charged ions. The electrons are, of course, negatively charged. The positively charged particles are much heavier than the electrons and are therefore accelerated more efficiently, while the electrons are more easily deflected from their



Hale Observatories Photograph

This cloud of cosmic debris seems to be sweeping outward from the site of an explosion that must have lit up this corner of the galaxy thousands of years ago. Undoubtedly this is the remnant of a supernova eruption whose high energy radia-

tion may be impinging on our atmosphere to produce thunderstorms. Located in the constellation Gemini, this vast cloud known as IC443 is estimated to be 8,000 light-years distant.

paths by an interfering force such as magnetic fields.

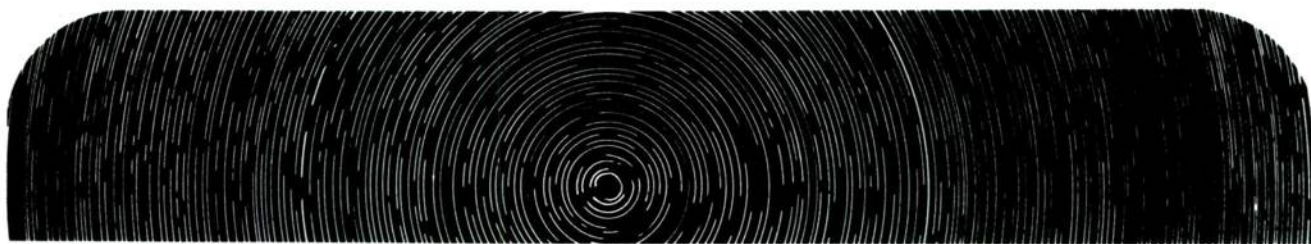
Electrons are deflected by the magnetic fields and spiral about them. In so doing they lose some of their energy, sometimes as light radiation, which produces the light from the supernova shell (the Crab nebula), or they lose their energy as radio emission. Many get out into interstellar space and there spiral about the interstellar magnetic field lines and radiate radio signals which produce the radio emission we observe to come from the Milky Way. So the electrons swing hither and thither through the magnetic fields in space, losing energy as they do so.

The positively charged particles, however, speed through space without taking much notice of the field lines at all, and they can ultimately hit Earth's atmosphere. The electrons also do this, but not quite as many electrons as ions make the trip down through the top of our atmosphere since there are so many forces acting to stop

them. For example, Earth's magnetic field itself can trap them in the Van Allen belts.

It is the heavy, positively charged ions (nuclei of helium, boron etc.) which reach us after their long journey through space. Journeys which probably took millions to tens of millions of years end with the creation of ionization in our atmosphere and clicks in Geiger counters. They create the well-known cosmic ray showers if they collide with a molecule in the high atmosphere. The positive and negative ions so produced are swept up by the updrafts in thundercloud formation; they separate out in the clouds, charges build up and lightning results.

So the lightning that sometimes kills people is all due to stellar explosions! For the first time we can point to a direct physical experience on Earth which is related to events in space. This new insight may make it possible to control the number of lightning flashes that might be produced in a storm. ☛



GAZER'S GAZETTE

Observing Double Stars

by
Thomas C. Bretl

For both the casual observer and the most serious telescope user, double stars have always been a favorite target — and for good reason. Some doubles possess striking colors that amaze the uninitiated stargazer, while others are such close pairs that their “splitting” is a moment of triumph for the patient observer. Perhaps more than any other class of objects, double stars serve both as a telescope’s final optical test and, at the same time, its owner’s first glimpse of the beauty that lies far beyond our own solar system.

If it were not for the wave nature of light, even a very small telescope could theoretically resolve any double star. High magnification would be the only requirement for separating very close components into two distinct pinpoints of light. Because light travels in waves however, when it

passes through a small opening, “diffraction effects” are observed. You can see these for yourself by doing the following experiment:

Use a pin or needle to make a small hole in a piece of cardboard and place it in front of a strong light (a slide projector is good) so that the light shines brightly through the hole. Next, using only the very point of the pin, put an even smaller hole in a second piece of cardboard. Hold this piece in front of your eye, look through the

These outstanding examples of double and multiple stars are portrayed as viewed in small telescopes. Albireo is the easiest of the three — seen here as it appears in a two or three inch telescope. Gamma Andromedae is a little more difficult and is shown as seen in a six inch scope. The famous “double double”, Epsilon Lyrae, is available to an experienced observer with a three inch refractor but a larger telescope will give the resolution shown here.



Gamma Andromedae



Albireo (Beta Cygni)



Epsilon Lyrae

Artwork by Victor Costanzo



Nestled at the heart of the Orion nebula is Theta Orionis, more commonly called the "Trapezium". This quadrilateral of four sixth magnitude stars is easily seen in a small telescope. Most photographs of this region are intended to reveal the nebula which in turn obscures the Trapezium stars. This is not an accidental association. These stars actually are only a few light-years apart and are responsible for much of the nebula's lumination.

Lick Observatory Photograph

pinhole, and examine the bright pinpoint of light from a distance of several feet.

Instead of a point of light, you will see a small bright disk surrounded by several fainter rings. This "diffraction pattern" is produced because the light "bends" as it passes through the pinhole and behaves as if many tiny wavelets were being generated across that small opening. These wavelets spread out in all directions. Some of them reinforce each other producing the bright disk and concentric rings, while others cancel each other, resulting in the dark gaps between these rings. The net result is an unexpected but beautiful "bull's eye target" pattern.

You may also notice that the diffraction pattern changes considerably as you vary the size of the hole next to your eye. The larger you make the hole, the smaller and less noticeable the pattern becomes. A very small hole, on the other hand, produces a large central disk with wide surrounding rings.

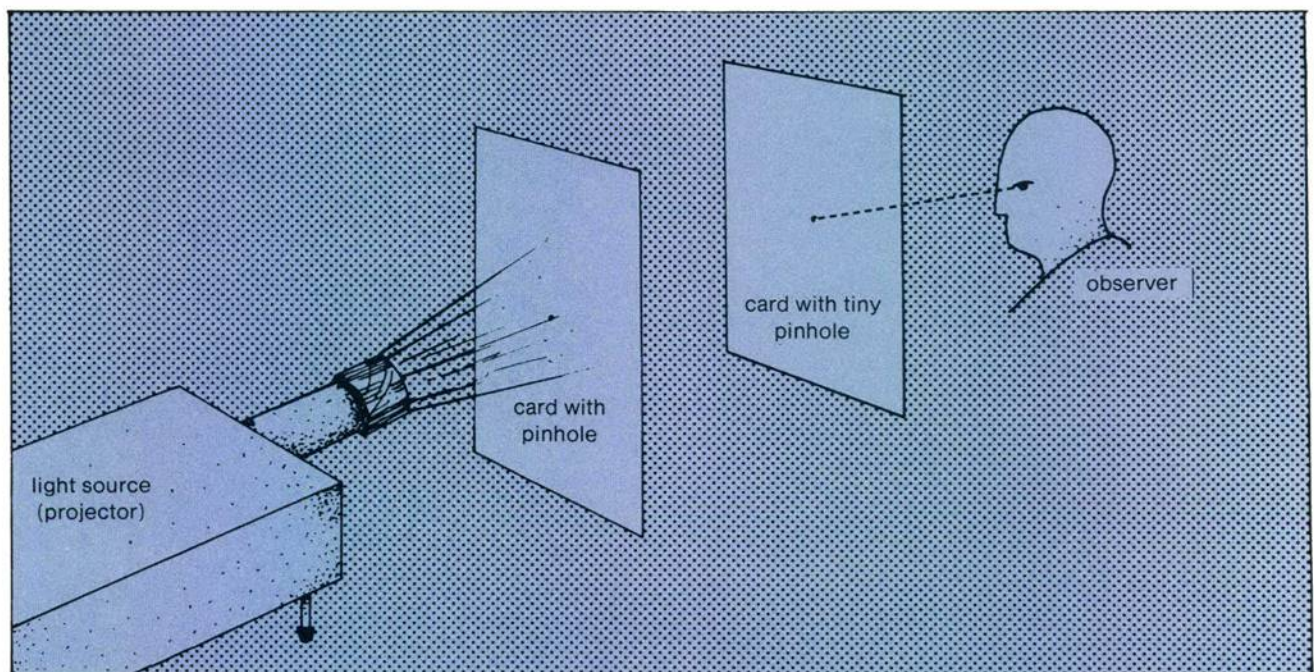
But how does this experiment relate to observing double stars? You can think of the bright pinhole of light as an artificial star, and the small opening in front of your eye as the aperture of your telescope. Your telescope, of course, is much larger than a pinhole and thus produces a much smaller diffraction pattern; nevertheless, because a telescope also greatly magnifies images, the diffraction pattern remains a very significant factor. If you use a magnification equal to 50

times your telescope's diameter in inches and observe a fairly bright star on a night of good seeing, you should be able to see the same kind of pattern you saw with the pinhole arrangement. Stellar images are not pinpoints of light at all, and if two stars are so close together that their "diffracted" images overlap, it may be impossible to distinguish them separately, regardless of the power you use. This is often the case with double stars.

Like the pinholes, the larger a telescope's aperture, the smaller the diffraction pattern will be. But there are two very important differences between pinhole stars and real stars — differences that greatly affect resolution.

First, real stars must shine through Earth's atmosphere, and an unsteady atmosphere can leave "theoretically resolved" stars hopelessly blurred. Only on nights when the air is still and the stars shine with a quiet, steady glow are diffraction patterns clearly visible, and unless the stars are showing fairly stable diffraction rings there is little hope of even approaching your telescope's theoretical limit, known as "Dawes' limit" (see table). Surprisingly, those sparkling clear winter nights are usually the worst for splitting close pairs. Stars that are so brilliant and twinkling to the naked eye perform a frustrating stellar dance in the field of a high power eyepiece.

The other important factor affecting the



Diffraction pattern demonstration experiment.

Spring Test Objects

Star	Mag.	Sep.	Test for:	Rec. Power	R.A.	Dec.
17 Draconis	5.0, 6.0	3.5"	1.5 inch	80x	16 ^h 36 ^m	+52°59'
90 Leonis	6.0, 7.3	3.4"	1.5 inch	80x	11 ^h 33 ^m	+16°56'
81 Virginis	7.5, 7.5	2.6"	2 inch	110x	13 ^h 36 ^m	- 7°45'
μ Draconis	5.0, 5.1	2.3"	2.4 inch	130x	17 ^h 32 ^m	+55°12'
12 Lyncis	5.2, 6.1	1.7"	3 inch	180x	6 ^h 44 ^m	+59°28'
	7.4	8.6"				
57 Cancri	5.9, 6.4	1.4"	4 inch	210x	8 ^h 53 ^m	+30°40'
Σ 460 Cephei	5.2, 6.1	0.9"	6 inch	330x	4 ^h 05 ^m	+80°38'
η Coronae Borealis	5.2, 5.7	0.5"	10 inch	600x	15 ^h 22 ^m	+30°23'

Famous Tests

Star	Mag.	Sep.	Test for:	Rec. Power	Color
α Ursae Minoris (Polaris)	2.5, 8.8	19.0"	2 inch	60x	Yellow-pale blue
γ ² Andromedae	5.1, 6.6	0.6"	10 inch	500x	Green-blue
β Orionis (Rigel)	0.3, 6.7	9.4"	4 inch	150x	White-blue
α Geminorum (Castor)	2.0, 2.9	1.9"	3 inch	160x	White-white
α Canis Majoris (Sirius)	1.6, 8.4	11.5"	6 inch and up	?	
ε Bootis	2.7, 5.1	2.9"	3 inch	150x	Orange-blue
α Scorpii (Antares)	1.2, 6.8	3.0"	any size	?	Red-green
ε ¹ Lyrae	5.1, 6.0	2.8"	2 inch	110x	Yellow-orange
ε ² Lyrae	5.1, 5.4	2.3"	3 inch	150x	Yellow-orange

Some Striking and Colorful Multiple Stars

Star	Mag.	Sep.	Color
γ Andromedae	2.3, 5.1	10.0"	Orange-blue
ι Cassiopeiae	4.7, 7.0, 8.2	2", 7"	Yellow-blue-blue
η Persei	3.9, 8.6	28.4"	White-blue
θ Orionis (The Trapezium)	6.0, 7.0, 7.5, 8.0	9", 13"	
ζ Ursae Majoris (Mizar)	2.4, 4.0	14.5"	White-white
γ Canum Venaticorum (Cor Caroli)	2.9, 5.4	19.7"	Yellow-yellow
δ Virginis	3.6, 3.6	5.2"	Yellow-yellow
β Scorpii	2.9, 5.1	13.7"	White-blue
α Herculis	3.5, 5.4	4.6"	Orange-green
θ Serpentis	4.5, 5.4	22.6"	Yellow-yellow
β Cygni (Albireo)	3.2, 5.4	35.0"	Yellow-blue
γ Delphini	4.5, 5.5	10.4"	Yellow-green

Telescope Resolution

Diameter of objective lens or main mirror	Maximum useful magnification	Average resolution limit	Dawes' limit
2 inch (50mm)	120x	4.0"	2.3"
2.4 inch (60mm)	150x	3.3"	1.9"
3 inch (75mm)	180x	2.7"	1.5"
4 inch (100mm)	240x	2.0"	1.1"
5 inch (125mm)	300x	1.6"	0.9"
6 inch (150mm)	360x	1.3"	0.8"
8 inch (200mm)	480x	1.0"	0.6"
10 inch (250mm)	600x	0.8"	0.5"
12 inch (300mm)	720x	0.7"	0.4"

A telescope's resolving power is best tested by observing a very close double star. If the two components of the double are about fifth magnitude and are separated by Dawes' limit for your telescope, then they represent the ultimate test. "Splitting" such doubles requires excellent

optics, clear dark skies, good seeing and an acute, experienced eye. (Even then the two stars will not be clearly split but will be "touching" each other.) The average resolution limit applies if one or more of these conditions is not met. See table on page 55 for test objects.

resolution of close doubles is the relative brightness of the two component stars. If their magnitudes differ greatly, light from the brighter one tends to flood over the fainter one, regardless of their separation. This is the case with many of the most famous difficult pairs. Sirius, for example, has an eighth magnitude companion at a separation that varies between 2 and 11 seconds of arc, but unless the atmospheric conditions are just right it is difficult or impossible to see in any size telescope.

Clearly Dawes' values do not apply when the components differ greatly in magnitude. And while it is true that an excellent telescope used by an experienced observer with very good eyesight can reach Dawes' limit on a night of good seeing, such optimum conditions are very seldom met. Nevertheless, Dawes' values remain today as well established standards of excellence that telescope makers continually strive to equal or surpass. To test your own telescope, your eyes, and the seeing conditions, try following these steps for best results:

1. Pick out double stars whose components are of approximately equal magnitude — preferably fifth or sixth magnitude to avoid bright diffraction rings.

2. Avoid pairs near the horizon where the light must pass through much more atmosphere.

3. Don't observe early in the evening. The atmosphere is often more turbulent right after sunset.

4. Try pairs at fairly wide separations first, and then work toward your telescope's limit. Even two or three times Dawes' limit is not always easy!

5. Experiment with different magnifications. High powers will have to be used to split close pairs. At least 150x, for instance, is needed to split a pair at 1.5 seconds of arc.

6. If the air is not steady and stellar images seem to be "ablaze", try again on another night. Check the accompanying tables for some good test stars.

Although it is easy to give a great deal of technical information about close double stars, it is a much more difficult task to describe the color and beauty of many of the wider pairs. So while most of this article is filled with words about diffraction patterns and double star tests, perhaps most of your time at the telescope will be spent observing such beautiful pairs as Albireo and Gamma Andromedae. Call them "magnificent", "exquisite" or "striking" if you will, but such words alone are certainly inadequate. Only "one more look" serves as a satisfying reminder of the splendid sights they truly are. 



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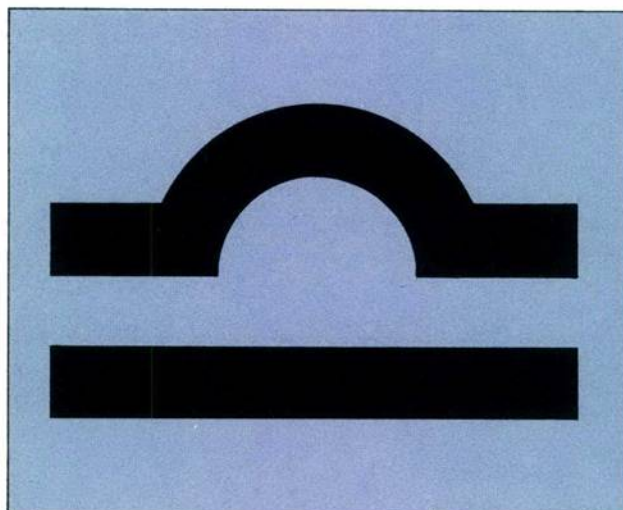
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CONSTELLATION CLOSE-UP

Libra

by
Thomas C. Bretl



As the belt of Orion fades into the evening twilight of early May, Libra “the Scales” rises into view in the southeastern sky. This quadrilateral shaped group of stars lacks the number of telescopic objects of the previous two zodiacal

constellations, but it offers some interesting double and variable stars together with a large, pale globular cluster which hints at the magnificence of the clusters to follow in coming months.

As we now know it, Libra is the only inani-

mate object of the zodiac. But at one time it was considered, first by the Greeks and then the Arabs, to be a western extension of Scorpius, which follows it across the southern sky. To the Greeks, Alpha and Beta Librae represented the outstretched claws of the scorpion, and today these stars still retain their tongue-twisting Arabic names, Zubeneshamali and Zubenelgenubi (the "Northern Claw" and "Southern Claw" respectively).

Despite its designation as Beta Librae, Zubeneshamali is the constellation's brightest star, shining at magnitude 2.7. It has the reputation of being the only prominent naked eye star to possess a definite greenish hue. Whether or not this reputation is well deserved is left to the reader to decide, for stellar colors are at best very subtle. However if you compare Beta to

Alpha, or to other stars of similar magnitude, the contrast in color should become apparent.

Zubenelgenubi, at magnitude 2.9, is also a noteworthy star. It is a double with a sixth magnitude companion at a very wide separation, and it serves as 1 of the 57 "navigational stars". It is a guide for the sky observer as well, for several other interesting objects can be found not far away.

About two degrees north of Alpha, for example, is Mu Librae, a much "closer" double star. The magnitudes of its components are 5.4 and 6.3, but at a separation of only 1.8 seconds of arc, Mu is a stiff test of resolving power for a three inch telescope. In fact, unless seeing conditions are excellent, Mu's rather low altitude as seen from the northern United States may make it difficult even in much larger instruments.

TABLE OF OBJECTS IN LIBRA

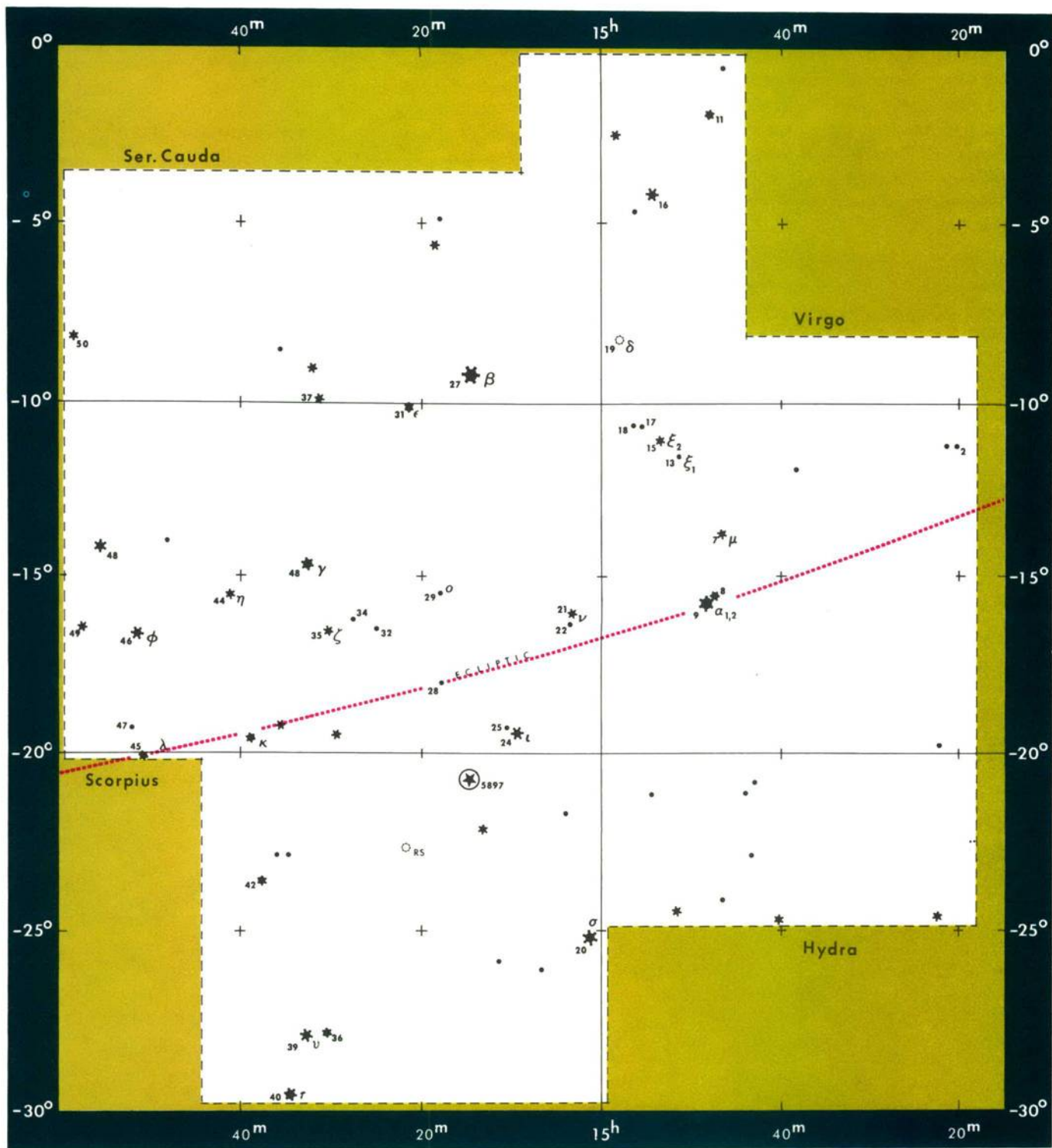
Double Stars

Star	Mag.	Sep.	Color	R.A.	Dec.
α	2.9, 5.3	230"		14 ^h 48 ^m	-15°50'
μ	5.4, 6.3	1.8"		14 ^h 48 ^m	-14°03'
ι	4.3-5.0, 9.7	58.6"	Yellow-purple	15 ^h 11 ^m	-19°43'

Globular Clusters

NGC	Mag.	Size	R.A.	Dec.
5897	11	7.3'	15 ^h 16 ^m	-20°56'

Epoch 1970



Map by Raymond G. Couthie

Stellar Magnitudes -1 0 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 & fainter

Diffuse Nebula Double Stars Variable Stars

Galaxies Planetary Nebula Open Star Clusters Globular Clusters



photograph by Thomas C. Bretl

Iota and Gamma Librae are the two fourth magnitude stars which together with Alpha and Beta form Libra's basic quadrilateral shape. Iota, like Alpha, is a wide double star, but because its companion is only magnitude 9.7, at least a two inch telescope will be needed to see it easily. Here is another chance to test your sensitivity to stellar color contrasts — Iota and its companion are listed as yellow and purple by Neale Howard in *The Telescope Handbook and Star Atlas*. Iota is also of interest as a variable star. Its magnitude fluctuates irregularly between 4.3 and 5.0. At times it may appear almost as bright as Gamma (magnitude 4.0), while at other times it should be only the equal of Mu (magnitude 5.0).

A much more punctual variable star is Delta Librae, four degrees northwest of Beta. Similar to Algol in Perseus, Delta is an eclipsing variable with a period of 2.33 days. Its magnitude fluctuates between 4.8 and 6.2, and you can easily follow its brightness changes by comparing it to some nearby stars. Mu, Nu (magnitude 5.3), and 5 Librae (magnitude 6.3) are all good for comparison purposes.

NGC-5897, Libra's only "prominent" nebula or cluster, is located about two degrees southeast

of Iota Librae. It is a large, faint globular cluster. Howard lists its visual magnitude as 11, while the *New General Catalogue* by J.L.E. Dreyer describes it as "pretty faint" and only "very gradually brighter toward the middle". A six inch telescope shows NGC-5897 as only a pale, hazy patch, and even a 12 inch seems unable to reveal it in any detail. Due to its southern declination, observers at lower latitudes may very well get better results. Wait for a night of good seeing in dark moonless skies for a decent view of this elusive cluster from the northern states.

In mythology, the mighty hunter Orion was stung and killed by the scorpion, and so their constellations were placed by the gods in opposite parts of the heavens. Scorpio, with its "Librid claws", is not long above the southeastern horizon before Orion has completely disappeared from the western sky. Thus Libra represents a time of transition. With its coming, we can bid a final farewell to the splendor of winter skies and prepare to greet the softly glowing star fields of the summer Milky Way. Next month we will turn our attention from the extragalactic wealth of the spring skies and begin to explore the beauty and mystery of the galaxy in which we live. 🐉

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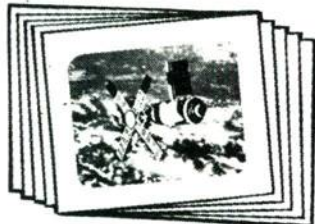
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